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Staff Report of the

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

METAL CONCENTRATIONS, LOADS, AND TOXICITY ASSESSMENT IN THE SACRAMENTO/SAN JOAQUIN DELTA ESTUARY: 1993-1995

June 1998

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Forward

This project has been funded by the Bay Protection Toxic Clean-up Program and by the Central Valley Regional Water Quality Control Board under contract number FG 2305 ES with the California Department of Fish and Game to conduct a survey of metals in the Sacramento/San Joaquin Delta Estuary. This document was prepared through agreement number 2-088-250 with the California State Water Resources Control Board. The contents of this document do not necessarily reflect the views and policies of the California Department of Fish and Game nor of the State Water Resources Control Board nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY The Sierra Nevada, Cascade, and Coast range mountains surrounding the Central Valley are rich in geological deposits of metal laden ores. Historic mining activity resulted in open mines and exposed tailings which leach metals into the Sacramento River and its' tributaries. Runoff from mining operations resulted in elevated metal concentrations in sediment and tissues of aquatic organisms and exceedances of water quality objectives. Although mine drainage is a significant contributor of metals to the system, metals also enter from other sources, including discharges from agriculture and urban areas. Metals in the upper and middle regions of the watershed have been linked to impacts in aquatic life using toxicity tests. However, metal concentrations and toxicity have not been well characterized in the Sacramento-San Joaquin River Delta.

The current study had three objectives: 1) to measure metal concentrations (i.e., copper, zinc, chromium, lead, cadmium, nickel, and arsenic) in the Sacramento River and the Sacramento-San Joaquin Delta during low and high flow periods using methods with low detection limits and ultra clean technique to define the extent of water quality objective exceedances, 2) to define the extent of metal associated toxicity throughout the Delta, and 3) to determine the metal loading patterns to the Delta, with emphasis on storm events. To address these objectives, fixed stations were monitored for metals and biotoxicity over multiple seasons and storm events. The biotoxicity project is discussed in separate reports (Deanovic et al., 1997 & 1998).

Evapoconcentration prior to analysis of field collected samples resulted in the detection of arsenic, cadmium, chromium, copper, lead, nickel, and zinc down to the low to mid parts per trillion range. This method vastly improved upon other analytical methods and resulted in detection limits which were among the lowest for the four programs monitoring metals in the Sacramento River Watershed. The advantage to the lower detection limits in this study is metals can be quantified at concentrations which are well below values set for water quality objectives. Furthermore, these lower detection limits minimize the frequency of non-detects and permit the detection of metals at and below actual instream values

Water samples for chemical analyses were collected during the relatively normal 1993 water year (WY93), critically dry 1994 water year (WY94), and high flow 1995 water year (WY95). Flows in the combined discharge of the Sacramento River and Yolo Bypass peaked at 135,000 on 28 March during WY93 and at 334,000 CFS on 13 March during WY95. As a result of the low rainfall during WY94, flows at Freeport did not exceed 30,000 and the Yolo Bypass had measurable flows above 1000 CFS on only four days.

Copper, zinc, chromium, and nickel concentrations averaged for 404 samples increased from WY93 and WY94 to WY95. These trends generally held true when WY93 was compared to WY94, but the magnitude of differences was reduced. These results indicate that extended periods of unusually high flows can result in marked increases in the average concentration of copper, zinc, chromium, and nickel. An analysis of average metal concentrations was performed at Greene's Landing on the Sacramento River to determine if the trends among water years held true within a station sampled during the same period. Similar to when concentrations from all stations were averaged, the average dissolved and total zinc, chromium, and nickel showed a trend of increased concentrations from WY93 to WY94 and from WY94 to WY95

During the dry WY94, total concentrations of copper, zinc, chromium, lead, and nickel were significantly associated with total suspended solids and flows. These significant relationships indicate these metals were bound to suspended sediments. These metal laden suspended sediments are in turn closely associated with flows during this critically dry year, such that their total concentrations increase with increasing flows. Dissolved copper, chromium, and nickel are also closely tied to flow conditions but were not associated with sediment particles. Therefore, concentrations of several metals would be expected to increase with increasing flow conditions and/or increased sediment load in the Sacramento River during dry conditions. These relationships did not hold true during the wet WY95. This may be a result of increased variety of suspended sediments sources, such as small tributaries on the western and eastern valley slopes, during this exceptionally wet year.

Significant relationships between total copper, zinc, chromium, and nickel reemerged again when data from the two water years were combined. Consistent with WY94 and WY95, total concentrations of these metals were significantly associated with suspended sediments and flow for WY94/95. Therefore, the relationships among dissolved concentration, total recoverable concentration, flow, and TSS are often metal dependent and different when extreme water years are compared or when water years are combined.

A special study was undertaken from 11 March to 13 March 1995 to track riverine sources of metal into the Delta. The samples were collected during the largest storm of the year when combined outflows from the basin peaked on 13 March at 297,000 CFS. Total metal concentrations on the upper Sacramento River peaked at Cottonwood Creek which carries metal laden water from several abandoned mines. From this point, concentrations decreased to Bend Bridge then increased again near Tehema. These results suggest undammed creeks, such as Springs, Reeds, Red Bank, Elder, Paynes, Antelope, and Mill, are important sources of metal enrichment in the river during high flow periods. Concentrations of all metals measured, except nickel, decreased downstream from Tehema then increased again near Colusa. This finding again suggests undammed creeks, such as Deer and Big Chico, are sources for metal enrichment in the river. Lower in the watershed, concentrations of all metals at Cache Creek were 150% to approximately 300% higher than at Cottonwood Creek, indicating this western drainage is a significant source of metals to the Yolo Bypass during high flows. Concentrations in the American and Feather Rivers were low. For reasons which are unclear, metal concentrations at Greene's Landing were much greater than those in the Feather and American Rivers, indicating an additional source of metals must have been present.

Dissolved metal concentrations were compared to the USEPA National Ambient Water Quality Criteria and the USEPA Proposed California Toxics Rule Criteria to determine if water quality objectives were exceeded in samples collected from 15 stations during WY94 and WY95. In

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summary, water quality objectives to protect aquatic life were never exceeded for 549 individual metal analyses.

Waters sampled from the Delta region were tested for toxicity during WY94 and WY95 using the EPA Three Species Tests to determine if aquatic life was impacted. In brief, 34 and 58 toxic events were detected during WY94 and WY95, respectively. Metals were never implicated in TIE studies conducted on the toxic samples. However, TIEs were not performed on all toxic samples due to budgetary limitations.

Riverine metal loads were estimated for the Delta based on measured total recoverable metal concentrations and instream flows. The load estimate for cadmium during the dry WY94 was the lowest of all metals, with 398 lbs. contributed to the Delta over the four month time period. Zinc load was the highest of all metals, ranging from 40,985 to 61,790 lbs. depending upon the method selected. When total loads into the Delta from the Sacramento River Watershed (i.e., Greene's Landing + Yolo Bypass) for WY95 are compared to WY94, percent increase in loads ranges from a low of 816% for cadmium to a high of 7,066% for nickel. To put these percentages in the context of pounds of metals added to the Delta, cadmium loads increased from 398 lbs. in WY94 to 3250 lbs. while nickel loads increased from 15,885 lbs. to 1,120,307 lbs. over the four month period of January through April 1995. These data indicate high flow years contribute significantly more metal loads to the Delta than critically dry year.

Metal loads calculated for the Sacramento River and Yolo Bypass during high flow characterized the contribution differences between these two sources of Delta water. Bypass water carried between 48% and 81% of the total load of the measured metals whereas the Sacramento River contributed between 19% and 52%. Sediment load entering the Delta from the Sacramento River and the Bypass was estimated to be 1,300,000 (34%) and 2,500,000 (66%) metric tons, respectively, from January through April 1995. The percentages of copper, zinc, and chromium from the two sources are nearly identical to those of sediment suggesting loads of these three metals are closely tied to sediment load. The bulk of nickel loads entering the Delta from the Sacramento River Watershed is primarily carried in the Bypass, but this contribution has no relationship to sediment loads. Nickel is common in the geological deposits of the western valley and may simply be washed down the bypass from local sources. Lead, chromium, and arsenic loads are generally equal in the Bypass and Sacramento River.

Loads were also calculated during a major storm event in March 1995. The primary sources of metal load to the upper Sacramento River during the storm was Cottonwood Creek. Additional significant sources of metal loads enter the river between Bend Bridge and the Ord Ferry Road Bridge, again point toward undammed creeks as sources along this stretch of river. Cache Creek contributed significant loads to the lower stretches of the watershed. In fact, Cache Creek loads exceeded those of Cottonwood Creek. These results confirm that Cache Creek is a major source of metal loads during high flow years. Load estimated during the storm often exceeded the average daily loads entering the Delta during WY95.

INTRODUCTION

BASIN DESCRIPTION

The Sacramento-San Joaquin Delta Estuary is ecologically, aesthetically, and economically significant to the state of California. The area comprises over 700 miles of interconnected waterways and encompasses 1153 square miles (Central Valley Regional Water Quality Control Board, 1994). The Delta, together with San Francisco Bay, is the largest estuary on the west coast of North America. It is fed by three main rivers, the Sacramento, the San Joaquin, and the Mokelumne, with a combined average unimpaired flow of about twenty-two million acre-feet per year. The Sacramento-San Joaquin Delta serves California as a significant water resource. Recognized beneficial uses include fisheries and wildlife habitat, agricultural supply, recreation, navigation, industrial process and municipal and domestic supply. Two statistics are presented below to help illustrate the environmental significance of the estuary to the people of California. First, over two-hundred-eighty species of birds and over fifty species of fish inhabit the freshwater portion of the estuary (San Francisco Estuary Project, 1992; Herbold and Moyle, 1989). This is considerably more than for any other water body in the State of California (San Francisco Estuary Project, 1992). Second, over half of all the drinking water for the State of California is pumped from the Delta (San Francisco Estuary Project, 1992). The Sacramento River contributes over 80% of the drinking water to the Delta, but is also a major conveyance route for contaminants from upstream sources to the Delta.

SOURCES OF METALS

The Sierra Nevada, Cascade, and Coast range mountains surrounding the Central Valley are rich in geological deposits of metal laden ores. Historic mining activity resulted in open mines and exposed tailings which leach metals into the Sacramento River and its' tributaries. Relatively few historic mining operations contributed the majority of metals to regional waters. From 1989-1991, the combined loads from all West Shasta District mines (i.e., Iron Mountain, Mammoth, Balaklala, etc.) accounted for over 95 percent of the total copper, cadmium, and zinc from inactive mine contributions to the Sacramento Valley (Montoya and Pan, 1992). Twenty-one of 31 inactive mines with perennial mine drainage caused downstream impacts based on exceeded water quality objectives and fish kills (Montoya and Pan, 1992). Runoff from mining operations resulted in elevated metal concentrations in sediment and tissues of aquatic organisms. Since the implementation of acid mine drainage controls on Iron Mountain Mine, exceedances of water quality objective have been drastically reduced (Conner *et al.*, 1998). The extent to which metals from mining operations are transported downstream to the Delta is unclear. Although mine drainage is a significant contributor of metals to the system, metals also enter from other sources.

Discharges from agriculture and urban areas are important sources of metals laden runoff to the Sacramento River. For example, 1,808,043 lbs. of copper (pentahydrate) were applied on rice crops in California during 1993 (Department of Pesticide Regulation, 1995). This quantity represents a 21% increase from 1991 applications (Department of Pesticide Regulation, 1993). By far, the majority of the rice cultivation in California occurs in the Sacramento River

Watershed. The transport, fate, and biotic effects of this metal under the current application methods are not completely understood. Another important source is urban runoff which carries metals from transportation and homeowner uses into regional waters. For example, total recoverable copper, zinc, and lead increased from upstream to downstream monitoring stations on the American River when concentrations were averaged from July 1994 to during 1995 (Larry Walker Associates, 1996). These increases are at least in part associated with wet weather urban inflows. Of interest to the Central Valley Regional Water Quality Control Board (CVRWQCB) are the effects upstream metal sources may have on aquatic life throughout the Watershed, including the Delta.

METAL TOXICITY

In order to understand the scope of metal impacts in the Delta, the spatial and temporal extent of effects in the upper Watershed must first be characterized. The Basin Plan of the Central Valley Regional Water Quality Control Board contains a narrative toxicity objective which states that all waters must be maintained free of toxic substances in concentrations that cause detrimental physiological responses in aquatic organisms (Central Valley Regional Water Quality Control Board, 1994). The Basin Plan also states that compliance with this narrative objective can be evaluated in a number of ways, including the use of the US EPA three species bioassay protocols and by comparing metal concentrations with available objectives and criteria. The Regional Board uses both approaches to evaluate threats posed by elevated metal concentrations. These bioassays measure changes in growth, survival, and/or reproduction of three species from three different phyla and trophic levels. Regional Board staff have relied on the use of the three species bioassays since 1986 to assess compliance the Basin Plan's narrative toxicity objectives.

From 1988 through 1990, Regional Board staff conducted periodic surveys of the Sacramento River Watershed for toxicity using the EPA protocols (Connor *et al.*, 1993). In terms of metals, the major findings of the surveys were that metals appeared to be responsible, at least in part, for impairments to *Ceriodaphnia* and *Selenastrum* (by comparing sites with low cell counts to other sites) in samples collected from the upper Sacramento River, and the Sacramento River from Shasta Dam to the City of Colusa. For both species, there was a trend of decreasing impairment that extended form the top of the Watershed until the City of Colusa. Several observations were consistent with the hypothesis of metal toxicity. First, water quality objectives for dissolved copper, zinc, and cadmium were frequently exceeded below both Shasta and Keswick Dams. Second, during the two and a half years of the study both ambient metal concentrations and the magnitude of *Ceriodaphnia* mortality decreased concurrently. Third, a Toxicity Identification Evaluation (TIE) conducted with *Ceriodaphnia* in Shasta Dam water suggested a metal toxicant. However, the observed *Ceriodaphnia* and *Selenastrum* impairments are not completely consistent with the existing metal concentration data. Copper, cadmium and zinc concentrations were higher in Keswick release water than in Shasta release water. This pattern does not correspond to the toxicity testing results, which indicates other parameters which were not monitored may play a role in toxicity.

Further studies in the Watershed were conducted to monitor discharges from major reservoirs on a quarterly basis for toxicity and metal concentrations from 1991-1992 (Goetzl and Stephenson, 1993; Connor *et al.*, 1994). Relatively few incidents of toxicity were detected during this testing period (Connor *et al.*, 1994). Results may have been influenced by altered climate conditions, such as the ongoing drought, as well as mine remediation projects. Significant toxicity to the freshwater alga *Selenastrum* was detected in the Sacramento River downstream from the Keswick Dam. Toxicity was detected in 75% of the samples collected from Keswick Reservoir (Connor *et al.*, 1994). When compared to 18 other sites sampled throughout the Watershed, samples collected downstream from Keswick Dam exhibited the highest frequency of toxicity and the greatest number of events when water quality objectives were exceeded for the metals monitored, primarily copper, cadmium, and zinc (Goetzl and Stephenson, 1993). There was a positive relationship between *Selenastrum* toxicity and exceeded metal water quality objectives. Because these results may have been influenced by drought conditions, additional studies were necessary to better characterize toxicity events during drought years.

The North Valley Study was conducted in 1993 to characterize water quality downstream from Shasta Dam, downstream from Keswick Dam, at Red Bluff, and at Hamilton City during a wet year (Bailey *et al.*, 1994). Toxicity to *Selenastrum* was detected in 67% of the samples, most frequently downstream from Keswick Dam. Follow-up studies were conducted from 1996-97 in this region as part of the Sacramento River Watershed. Larsen *et al.*, (1998) reported a lack of *Selenastrum* toxicity in the region during this time period.
Toxicity Identification Evaluation (TIE) procedures suggested the metals copper and zinc were responsible. Several waters collected from July 1993 through August 1993 resulted in significant mortality to *Ceriodaphnia*. TIEs suggested that chronic zinc toxicity increased the susceptibility of the daphnids to opportunistic microorganisms (Reyes *et al.*, 1994). The toxicity studies conducted since 1988 suggest differences in toxicity occur during wet and dry years.

Metal related toxicity and metal analyses have been not limited to the upper reaches of the Watershed. American River water impaired *Ceriodaphnia* performance in 56% of the samples (Connor *et al.*, 1993). Regarding these impairments, 55.6 % were of survival. The frequency of impairments was greater at Discovery Park and at other sites that are potentially impacted by Sacramento urban area discharges than at Nimbus Dam (56% relative to 20%). A toxicity identification evaluation conducted on one sample suggested the *Ceriodaphnia* impairment potentially was due to cationic metal toxicity.

The combined results of toxicity testing conducted since 1988 provide some indication of metals impacting aquatic life from mining and urban sources. However, no studies have been undertaken in the Delta to determine the overall importance of metals and toxicity on aquatic resources.

WATER QUALITY CRITERIA

The Central Valley Regional Water Quality Control Board (CVRWQCB) is not only interested in characterizing toxicity to aquatic organisms, but also in characterizing regional waters for compliance with water quality objectives. However, in the past it was difficult to use monitoring data to evaluate compliance with existing metal water quality objectives because either the detection limits were too high (i.e., above actual instream concentrations) or the quality assurance and control were not rigorous (e.g., low detection limits). Further difficulty has been encountered because of changes in water quality objectives in California. During 1995, criteria used to protect aquatic life from inorganic constituents were promulgated in the California Inland Surface Waters Plan. These objectives were based on the US EPA National Ambient Water Quality Criteria. However, values for the Inland Surface Waters Plan were expressed as total recoverable metal, while the US EPA criteria were expressed as dissolved metal (Marshack, 1995). The Inland Surface Waters Plan was repealed in 1994 resulting from a legal challenge, leaving California without enforceable numerical water quality objectives for priority toxic pollutants in surface waters as required for each state by the Clean Water Act. In 1997, the US EPA proposed to promulgate water quality criteria for priority toxic pollutants for California's inland surface waters by developing the California Toxics Rule. Criteria currently used as guidance for the CVRWQCB to protect freshwater aquatic life from inorganic constituents are the US EPA Proposed California Toxics Rule and the US EPA National Ambient Water Quality Criteria. As of 1998, both criteria are expressed as dissolved metals (Marshack, 1998).

BAY PROTECTION AND TOXIC CLEANUP PROGRAM

In 1989, the California Water Code was amended to create the Bay Protection and Toxic Cleanup Program (BPTCP). The three primary goals of the program are to 1) identify toxic hot spots, 2) develop sediment quality objectives, and 3) remediate toxic hot spots, either through cleanup efforts, mitigation or prevention. Section 13391.5 of the Water Code defines toxic hot spots as: "....[L]ocations in enclosed bays, estuaries, or adjacent waters in the 'contiguous zone' or the 'ocean' as defined in Section 502 of the Clean Water Act (33. U.S.C. Section 1362), the pollution or contamination of which affects the interests of the State, and where hazardous substances have accumulated in the water or sediment to levels which (1) may pose a substantial present or potential hazard to aquatic life, wildlife, fisheries, or human health, or (2) may adversely affect the beneficial uses of the bay, estuary, or ocean waters as defined in the water quality control plans, or (3) exceeds adopted water quality or sediment quality objectives."

The BPTCP identifies five conditions that are used to define toxic hot spots.

1. Exceedance of water quality objectives
2. Toxicity associated with a toxic pollutant
3. Exceedance of tissue contaminant levels
4. Impairment of resident organisms
5. Degradation of populations or communities associated with toxic pollutants

Using Bay Protection Toxic Cleanup Program funds, the Central Valley Regional Water Quality Control Board conducted a study from May 1993 to December 1996 to characterize toxicity, metal concentrations, and metal loads in the Delta. The overall focus of this study was to determine if there were metal impacts in the Delta, and if so, identify wether the impacts were a result of transport or *in situ* processes. Prior to this study, there had been ongoing metals monitoring in the Delta for many years. However, the past monitoring was deficient in three general areas. First, as stated above, quality assurance and control were not rigorous and detection limits were too high. Second, the existing objectives did not address situations where many metals (as well as organic compounds) are present. Toxicity tests conducted concurrently with metals monitoring were needed to determine if metals are contributing to a toxicity problem in the Delta. The situation of multiple compounds potentially working additively to cause toxicity is potentially important in the Delta because of the high load and diversity of inputs. Third, most of the annual metal load to the Delta is associated with major storm events. Past monitoring within the Delta had not adequately characterized metal levels and loads to the Delta during storm events.

The current study had three objectives: 1) to measure metal concentrations (i.e., copper, zinc, chromium, lead, cadmium, nickel, and arsenic) in the Sacramento River and the Sacramento-San Joaquin Delta during low and high flow periods using methods with low detection limits and ultra clean technique to define the extent of water quality objective exceedances, 2) to define the extent of metal associated toxicity throughout the Delta, and 3) to determine the metal loading patterns to the Delta, with emphasis on storm events. To address these objectives, fixed stations were monitored for metals and biotoxicity over multiple seasons and storm events. The biotoxicity project is discussed in separate reports (Deanovic *et al.*, 1997 & 1998).

MATERIALS AND METHODS

SAMPLE LOCATIONS

Water samples were collected for metal analyses and toxicity assessments during the 1993, 1994, and 1995 water years. Sampling sites for metal analyses included main river inputs to the Delta, back sloughs and small upland drainages, urban runoff receiving areas, and points along the path of water movement across the Delta (Fig.1; Table 1). In addition, samples were collected to track riverine metals sources into the Delta (Fig. 2; Table 1). Additional sampling sites were selected for toxicity assessments (Deanovic *et al.*, 1996; 1998) The specific location of each site is described in Appendix A.

SAMPLE COLLECTION AND STORAGE

Metal Analyses

River samples for total recoverable and dissolved metals analyses were collected by Regional Board staff. All samples were collected from beneath the water surface by boat at a bridge or as far away from the bank as was safe in a rapidly moving section of the water course. The samples were collected through meticulously cleaned tubing that was inserted through 25 feet of PVC one inch pipe (Goetzl and Stephenson, 1993). The use of the pipe allowed the sampling point to be about 20 feet from the shore and thus minimized edge effects. All samples were pumped from the point of collection (using a peristaltic pump) through 25 feet of acid-cleaned tubing directly into an analysis bottle containing acid. The tubing ended in a relatively dust free sampling box which contained the sampling bottles. The bottles were handled without opening the box through gloved port holes. The tubing and the box minimized the exposure of the samples to airborne contamination. The exception to this procedure was the sampling during high flow events. This sampling used a composite sampler instead of a glove box for sample collection. All analysis bottles were double bagged except while being filled. All samples collected for determining the concentration of dissolved metals were filtered through a 0.45 micron filter that attached to the end of the tubing. At each site water conditions, sampling conditions, water temperature, pH and EC were recorded. After collection, all samples were triple bagged and placed in a dust free container until shipped to the Moss Landing Mussel Watch lab via UPS overnight delivery. The details of the sampling equipment and procedures are described in the Field Sampling QA/QC Manual for the project (Connor *et al.*, 1993)

Toxicity Samples

Surveys were conducted from May 1993 to December 1996. To facilitate water collection, Delta sites were divided into two monitoring zones; each was sampled approximately once a month. Water sampling was conducted by Regional Board staff using techniques developed by Mr. Mark Stephenson. All sample bottles and sampling supplies (tubing and filters) were meticulously cleaned. Water was collected from mid-channel by boat or from bridges. Samples were collected during low tide to ensure maximum freshwater composition. All samples were collected from beneath the water surface in a rapidly moving section of the water course. All water samples were immediately placed on ice for transportation to the laboratory where they were stored at 4°

C. If a sample was determined to be toxic and no metal analyses sample were collected from the field site, then sub-samples were taken from the bioassay water and placed in one liter polyethylene bottle (containing nitric acid) for determination of total recoverable and dissolved (1.0 μm filtered) metal concentrations.

METAL ANALYSES

Metal concentrations were analyzed by the California Department of Fish and Game Lab at the Moss Landing Marine Lab, using ultra-clean facilities and graphite furnace atomic absorption spectrophotometry (Goetzl and Stephenson, 1993). Twenty percent of the samples were split samples analyzed by Mike Gordon in a separate facility at Moss Landing. Samples were analyzed using an evapo-concentration technique to obtain low detection limits. The essence of this procedure is that a sample is concentrated twenty-five fold by evaporation followed by an acid-treatment to re-dissolve the sample. This procedure can achieve detection limits in the parts per trillion range.

AA Methods (Trace Metal Water Lab)

Samples were analyzed by flameless AA on a Perkin-Elmer Zeeman 5000 Atomic Absorption Spectrophotometer equipped with an HGA 500 graphite furnace at the Salinas facility of Moss Landing Marine Laboratories. Due to high concentrations, a few samples were analyzed using flame AA on a Perkin-Elmer 603 AAS. Samples and standards were prepared in a laminar-flow clean bench inside the trace metal lab. To ensure accurate results, the samples were analyzed using the stabilized-temperature platform technique. The characteristic mass for each element is computed to ensure the proper functioning of the Zeeman AA. Samples may be analyzed using a matrix modifier made up from ultra-clean chemicals. When no modifier is used, high-char temperatures allow interfering matrix components of the sample to be volitized prior to atomization. Single spike additions to samples allow a check for recovery when standards are linear. Finally, the SLRS-2 (1993-94 samples) or SLRS-3 (1994-95 samples) river water standard reference material is evapoconcentrated and analyzed with each set of samples.

AA Methods (Mussel Watch Lab)

The Mussel Watch Lab is located at the Moss Landing Marine Laboratories in Moss Landing. Samples were analyzed by furnace AA on a Perkin-Elmer Zeeman 3030 Atomic Absorption Spectrophotometer with an AS60 auto-sampler and HGA 500 graphite furnace. Samples, blanks, matrix modifiers, and standards were prepared using clean techniques inside a clean lab. Milli-Q water and ultra-clean chemicals were used for all standard preparations. To ensure accurate results the samples were analyzed using the stabilized-temperature platform technique. Matrix modifiers were used when the components of the matrix interfere with adsorption. The matrix modifier was arsenic in all samples and lead in 1993-94 samples. Blanks and a standard reference material (SLRS2 river water), were evapoconcentrated and analyzed with each set of samples.

TOXICITY TESTING PROCEDURES

Standardized U.S. EPA freshwater bioassay protocols were used for this study (U.S. EPA, 1994). The three organisms used in the laboratory assays were: (1) a primary producer, the green algae *Selenastrum capricornutum*; (2) a primary consumer, the zooplankton *Ceriodaphnia dubia*; and (3) a secondary consumer, the fathead minnow, *Pimephales promelas*. A complete description of the methodologies applied in testing ambient water samples for toxicity can be found in Deanovic *et al.*, (1996, 1998). When toxicity was detected in a sample, follow-up toxicity identification evaluation (TIE) procedures coupled to analytical chemistry were implemented to help determine the cause. Briefly, samples are tested for toxicity following several manipulation designed to render certain chemical/elemental constituents in the sample non-toxic. In addition, methods are applied to recover the chemical/elemental causes of the observed toxicity. A complete description of TIE procedures can be found in U.S. EPA (1991, 1993) and Bailey *et al.*, (1996).

Statistical Methods and Definition of Toxicity

Toxicity was defined as a statistically significant difference ($p<0.05$) between a sample and the laboratory control. Bartlett's Test for homogeneity of variance was run on all fish growth and mortality, *Ceriodaphnia* reproduction, and algal growth data. When the data variance was homogeneous, the samples were compared to the controls using Analysis of Variance and Dunnett's mean separation tests. If the data variance was not homogeneous, then comparisons were made against the control using Kruskal-Wallis and Dunn's non-parametric multiple comparison. *Ceriodaphnia* survival was compared against the control with a Fisher's Exact Test. No statistical analyses were conducted on TIE results. Acute toxicity was defined as a statistically significant difference in mortality within 96 hours between an ambient water and laboratory control sample.

METAL LOADS

Water Years 1993, 1994, and 1995

Water year 1993 (October 1992-September 1993) was classified as a relatively normal water year in the Sacramento Basin. Water year 1994 (October 1993-September 1994) was classified as critically dry and is identified in this report as a "dry year". During such dry years, the Sacramento River serves as the primary source of water transport from the Basin to the Delta. Conversely, water year 1995 (October 1994-September 1995) was characterized by high flows which resulted in water transport to the Delta via the Sacramento River and the Yolo Bypass. For the purposes of this study, water year 1995 was classified as a "wet year".

Flow Rates

Daily water discharge rates from the Sacramento River at Greene's Landing and for the Yolo Bypass at Prospect Slough were obtained from U.S.G.S. flow gauges (U.S. Geological Survey 1994, 1995).

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Load Calculations

Bulk daily metal loads (kg/day) at Prospect Slough and the Sacramento River at Greene's Landing were calculated for copper, zinc, chromium, lead, cadmium, nickel, and arsenic from January through April 1994 and 1995. Mercury loads were not included in this report but can be found in Foe and Croyle (1998). Two methods were employed to calculate loads. First, models were developed for each metal using a linear regression with flow as the independent variable and total measured concentration as the dependent variable. Each model was tested for significance (Steel and Torrie, 1960). When models were significant, daily flows were entered into the linear regression equation to obtain daily predicted metal concentrations. Daily predicted concentrations (µg/l) were then multiplied by daily flow to obtain model generated estimates of metal load. Second, when the model was not significant, loads were calculated by multiplying flow by the average metal concentration (µg/l) measured in field samples ("Average Concentration Method"):

$$(\text{Metal concentration}) \times (2.445 \times 10^{-6}) \times (\text{Flow})$$

Total load was estimated by summing the daily loads for each period. Loads were also calculated using data from the Sacramento Coordinated Water Quality Monitoring Program's Ambient Monitoring Program, using the Average Concentration Method. This permitted a comparison of load estimates calculated for two independent monitoring efforts on the Sacramento River at Greene's Landing and River Mile 44. The programs relied on different collection methods, sample frequencies, sample locations, and temporal pattern of sampling.

WATER QUALITY OBJECTIVES

US EPA Proposed California Toxics Rule and the US EPA National Ambient Water Quality Criteria (expressed as four day average criteria) to protect freshwater aquatic life (Marshack, 1998) from inorganic constituents were compared to dissolved metal concentrations at 15 stations to determine the spatial and temporal extent that objectives were exceeded during the study. Criteria were expressed as four day average concentrations associated with the hardness measured in samples collected from each site concurrent with metal analysis samples.

QUALITY ASSURANCE PROGRAM

The purpose of the Quality Assurance Program was to ensure the data were generated under conditions that accurately reflected the quality of the water sample. Standardized procedures were followed in all aspects of research. These methods are described in the Project Quality Assurance plan designed for this project. (Connor *et al.*, 1993). Both accuracy and precision were addressed in the quality assurance/quality control (QA/QC) document.

Metal Analyses

Field The field portion of the QA program consisted of collecting blanks and field duplicates. Field blanks were collected to insure that samples were not contaminated by any aspect of the collecting procedure. A five gallon carboy of ultra pure water was brought to a field site. Water was pumped from the carboy following the same procedures which were used when a routine field sample was collected.

On 22 occasions duplicate water samples were collected from randomly selected sites to the characterize the reproducibility of the measurements performed by the Trace Metal Laboratory and the Mussel Watch Laboratory. Field duplicates consisted of collecting two samples with a ten minute lapse between samples.

Laboratory The laboratory component of the QA program was focused toward characterizing contamination of sampling equipment and assessing measures of precision and accuracy. Laboratory blanks were collected to insure that the sampling equipment was not contaminated. This consisted of pumping ultra pure water (18 megaohm deionized) water through the peristaltic tubing and filter apparatus into an analysis bottle. Precision is a measure of the reproducibility of a test method when it is repeated under controlled conditions. As described in the QA/QC documents (Goetzl *et al.*, 1994; 1995), precision was evaluated by two methods: (1) inter-laboratory splits of water between the Trace Metal Laboratory and Mussel Watch Laboratory, and 2) an intra-laboratory repeated analysis of the standard reference materials (SRMs) by the Mussel Watch Laboratory. The agreement between the amount of a component measured by the test method and the amount actually present is a measure of accuracy of the test method. To measure accuracy, one (SRM) was run for approximately every 25 samples analyzed. The standard reference materials used were Riverine Water SLRS-2 and SLRS-3 (for 1993-94 samples and 1994-95 samples, respectively) from the National Research Council of Canada.

Toxicity Assessment

Standard procedures were followed in all aspects of the toxicity assessment. Monthly reference toxicant tests, consisting of five to six known concentrations of NaCl in laboratory control water, were conducted for each species. Chronic LC_{50} and EC_{50} concentrations were calculated to ascertain changes in animal sensitivity throughout the time period of the study. A complete description of quality assurance measures can be found in the Delta Monitoring Quality Assurance Project Plans (Connor *et al.*, 1995; Nielsen *et al.*, 1995).

RESULTS AND DISCUSSION

QUALITY ASSURANCE/QUALITY CONTROL

Metal Analyses

Field On five occasions field blanks were collected; once for dissolved metals and four times for total recoverable metals (Table 2). Contamination was negligible with no metals detected above 1 ppb. This finding is consistent with the minimal contamination reported when the technique was applied to quantify metal concentrations in Central Valley reservoir releases (Goetzl and Stephenson, 1993). Field duplicates were collected on 22 occasions with a resulting average difference between the two laboratories of 18% (Table 3; Goetzl *et al.*, 1995). Values not detected by either laboratory or very close to the detection limit were not included.

Laboratory Laboratory blanks were collected on seven occasions with 56% of the individual metals data quantified as below the detection limits from the method (Table 4). Contamination was negligible with only one metal detected above 1 ppb when metals were detected in the laboratory blanks,. These findings were consistent with those in Goetzl and Stephenson (1993), indicating the sampling gear was relatively free of metal contamination. Laboratory blanks were also collected to determine if filtration of samples prior to conducting toxicity tests resulted in contamination (Table 5). Of three samples tested for filtration effects, there was no consistent pattern of removal or contamination for the seven metals. Therefore, 0.45 μm filtration of samples prior to conducting toxicity tests did not appear to significantly alter metal concentrations.

Intra-laboratory precision was assessed between five and eight times depending on the metal. The average difference between the certified and mean detected values ranged from 3 to 14% (Goetzl *et al.*, 1995). Field splits in this study not only quantified inter-laboratory precision, but they also integrated variability from the ten minute lag between sample collection. Inter-laboratory precision was shown to be within an average of 14% and 18% of each other for the 1993-94 and 1994-95 samples, respectively (Table 3; Goetzl *et al.,* 1995). Values that were not detected by either lab or values that were very close to the detection limit were not included in the precision calculation. In addition, the calculation did not include values that differed between labs by a large amount (e.g., outliers). Those values were highlighted in the report. Single-laboratory precision was analyzed using the SRM SLRS-2 and SRM SLRS-3 for the 1993-94 and 1994-95 samples, respectively. All of the values for the elements were within the 99% confidence limits of the SRMs.

Approximately one standard reference material (SRMs) was analyzed for every 25 samples to address the accuracy of the evapoconcentration method. The SRM metal values were all greater than ten times the detectable limits with the exception of silver (1993-94 and 1994-95 samples) and lead (1994-95 samples) (Goetzl *et al.*, 1994; 1995). All of the 1993-94 SRMs were within the warning limits, which are ± 15% greater than the 95% SRM confidence limits. All of the 1994-95 SRMs were within the warning limits, with the exception of lead. The SRM for lead used with the 1994-95 samples was considerably lower than the lead SRM used with the 1993-

94 samples. The new value was very close to the detection limit, making it difficult to analyze. All values (in both years) were within the warning and control limits (± 20% greater than the 95% SRM confidence limits) with the exception of lead. All but one lead SRM value in the 1994-95 document was between the warning and control limits. These results indicate, with few exceptions, a high level of accuracy and precision were associated with the evapoconcentration method utilized in this program.

Toxicity Assessment
Between test variability was assessed for this study with reference toxicant tests. USEPA (1994) recommends reference toxicant testing to ascertain whether changes in animal sensitivity occurred. Of particular interest are the detection of outlier values exceeding the upper or lower 95 percent confidence limits of the long term mean or of general trends in changing animal sensitivity. During the 1993-1994 phase of testing, neither were noted in the control charts of any of the test species (Deanovic *et al.*, 1996). One outlier occurred in the LC_{50} chart for *Pimephales* mortality. In this particular case, the fathead minnow was less sensitive to NaCl. All quality control measurements showed acceptable characteristics suggesting toxicity test data were reliable. One outlying value each occurred in the *Ceriodaphnia* reproduction and survival test, the *Selenastrum* and *Pimephales* growth assays, and the fish mortality data during the 1994-1995 phase of testing (Deanovic *et al.*, 1998). The USEPA (1994) suggests one outlying value may be expected to occur by chance when 20 or more events are compared. Twenty-one to twenty-four data points are presented in the control charts, therefore, quality control measurements were acceptable and indicated the bioassay data were reliable. A more complete description of the Quality Assurance information for the toxicity studies can be found in the toxicity reports (Deanovic *et al.*, 1996; 1998)

HYDROLOGICAL CONDITIONS

Water samples for chemical analyses were collected and toxicity assessments were performed during the relatively normal 1993 water year (WY93), critically dry 1994 water year (WY94), and high flow 1995 water year (WY95). Flows in the combined discharge of the Sacramento River and Yolo Bypass peaked at 135,000 on 28 March during WY93 and at 334,000 CFS on 13 March during WY95 (U.S. Geological Survey, 1993; 1995). As a result of the low rainfall during WY94, flows at Freeport did not exceed 30,000 and the Yolo Bypass had measurable flows above 1000 CFS on only four days (Fig. 3; U.S. Geological Survey, 1994).

METAL ANALYSES

Evapoconcentration of field collected samples resulted in the detection of arsenic, cadmium, chromium, copper, lead, nickel, and zinc down to the low to mid parts per trillion range (Table 6). This method vastly improved upon other analytical methods and resulted in detection limits which were among the lowest for the four programs monitoring metals in the Sacramento River Watershed (Table 6). For example, detection limits for the US Bureau of Reclamation analyses of metals at the Iron Mountain Mine Treatment Facility currently exceed both the instream cadmium concentrations and water quality objective for water with a low hardness. The advantage to the lower detection limits in this study is metals can be quantified at concentrations which are well below values set for water quality objectives. For example, the detection limit for cadmium in this study was two parts per trillion (ppt) while the lowest US EPA National Ambient Water Quality Criteria for protecting freshwater aquatic life is 370 ppt (Marshack, 1998). Furthermore, these lower detection limits minimize the frequency of non-detects and permit the detection of metals at and below actual instream values (Goetzl and Stephenson, 1993).

Sacramento/San Joaquin River and Delta

Four hundred and four water samples were collected from 37 stations for analysis of dissolved and total recoverable metal concentrations (Appendix B). When total recoverable and dissolved concentrations were independently averaged for all samples collected, a trend of increasing copper, zinc, chromium, and nickel concentrations was observed from WY93 and WY94 to WY95 (Table 7). These trends generally held true when WY93 was compared to WY94, but the magnitude of differences was reduced. These results indicate that extended periods of unusually high flows can result in marked increases in the average concentration of copper, zinc, chromium, and nickel. However, other metals did not exhibit a consistently strong association with peak flows. For example, total recoverable and dissolved arsenic showed a trend of decreasing average concentration from WY94 to WY95. Cadmium, on the other hand, had a distinctly different profile with total recoverable concentrations increasing and dissolved concentrations essentially remaining unchanged during the three water years. Average total recoverable lead concentrations decreased slightly from the WY93 to WY94, then increased by more than three fold in WY95, while the average dissolved concentration increased from WY93 to WY95. It should be noted that averaging the metal analyses for all stations can be problematic because of different sample collection frequencies at each station and different stations monitored among water years.

An analysis of average metal concentrations was performed at Greene's Landing on the Sacramento River to determine if the trends among water years held true within a station sampled during the same period. Similar to when concentrations from all stations were averaged, the average total and dissolved zinc, chromium, lead, and nickel showed a trend of increased concentrations from WY93 to WY94 and from WY94 to WY95 (Table 8). Average dissolved concentrations of cadmium behaved in a similar fashion as the entire data set, with no changes among water years. However, average total cadmium concentrations had a different pattern with a decrease from WY94 to WY95. Average dissolved copper concentrations were also inconsistent with the combined data with no difference between WY93 and WY 94 but matched the trends for the combined data from WY94 to WY95. Arsenic was not measured at Greene's Landing during WY94 and therefore changes during water years could not be compared at this station. With the exception of dissolved cadmium concentrations, the concentration of the monitored metals appear to be closely tied to flow or other parameters related to flow.

Dissolved and total metal concentrations collected from the Sacramento River at Greene's Landing were regressed against each other, flow at Freeport, and total suspended solids (TSS) for

WY94, WY95, and combined WY94 and WY95 (WY94/95) to determine if these factors were interrelated. The number of significant relationships between dissolved metals, total metals, flow, and TSS declined from 15 in the critically dry WY94 to eight in the high flow WY95 (Tables 9 and 10). When data from water year 1994 and 1995 were combined, 17 of 35 regression analyses were significant (Table 10).

During the dry WY94, total concentrations of copper, zinc, chromium, lead, and nickel were significantly associated with total suspended solids and flows (Table 9; Figs. 4-13). These significant relationships indicate these metals were bound to suspended sediments. These metal laden suspended sediments are in turn closely associated with flows during this critically dry year, such that their total concentrations increase with increasing flows. Dissolved copper, chromium, and nickel are also closely tied to flow conditions but were not associated with sediment particles (Table 9; Figs. 14-19). In addition to being related to flow and TSS, total concentrations of lead and chromium could be used to predict dissolved concentrations due to a significant relationship between the analytical forms of the metals (Table 9; Figs. 20 & 21). Both total and dissolved cadmium concentrations were unrelated to flow and TSS, which is consistent with the lack of a trend reported in Tables 7 and 8. Therefore, concentrations of several metals would be expected to increase with increasing flow conditions and/or increased sediment load in the Sacramento River during dry conditions.

These conclusions did not necessarily hold true during the wet WY95. Of particular interest is the absence of significant relationships between flows and total and dissolved metal concentrations in WY95 when compared to WY94 (Tables 9 and 10; Figs. 22-35). The breakdown in this relationship may be a result of increased sources of suspended sediments in the system during this exceptionally wet year when compared to the dry WY94. The major sources of suspended sediments in the lower watershed during a dry water year are the Sacramento, Feather, and American Rivers, whereas smaller tributaries on the western and eastern valley slopes may contribute significantly to the total suspended solids during a wet year. The different geological sources of these sediments may result in different binding affinities for the metals and could therefore disrupt the relationships between total metals, total suspended solids, and flow. However, this is conjecture at this point and would require further study to clarify the role of small tributary sediments during high flow conditions.

Although the relationships between flow and metal concentrations broke down during high flows found in WY95, total copper, zinc, and cadmium were still significantly related to TSS indicating these metals are bound to suspended sediment particles during both dry and wet years (Table 10; Figs. 36-38). The level of significance for this relationship with cadmium ($R^2 = 0.92$) is drastically different than in WY94, again possibly pointing toward further evidence that additional sources of suspended sediments enter the system during high flows (Table 10, Fig. 39). As in WY94, total and dissolved concentrations for some metals (i.e., copper and lead) were related (Table 10; Figs. 40-41). Therefore, as dissolved concentrations of lead increased at Greene's Landing, one could predict that total recoverable lead concentrations would increase as well.

Significant relationships between total copper, zinc, chromium, and nickel reemerged again when data from the two water years were combined (Table 11; Figs. 41-49). Consistent with WY94 and WY95, total concentrations of these metals were significantly associated with suspended sediments and flow for WY94/95 (Table 11; Figs. 41-49). One could apply the relationships between flow and total concentrations of these metals as a predictive tool. Although the relationships are significant, there is considerable variability about the regression line, especially during high flows (Fig. 46). Therefore, predicting total concentrations from flow would have a wide margin of error. Dissolved chromium, lead, and nickel also were significantly related to TSS and flow (Table 11; Figs. 50-55). Furthermore, the dissolved forms of chromium and lead were associated with the total recoverable form. This relationship was also significant for copper and nickel, but the dissolved forms of these two metals were not associated with suspended sediments. Therefore, the relationships among dissolved concentration, total recoverable concentration, flow, and TSS are often metal dependent, different when extreme water years are compared and when water years are combined. Additional research would be required to determine if consistent relationships occurred during dry and wet years and blind studies may be necessary to determine the accuracy of using these relationships as a predictive tool for metal concentrations in the Sacramento River.

Relationships found between flow, TSS, and metals during this study should not be applied to times of the year other than when winter flows occur because the relationships may not apply. For example, the Sacramento County's Ambient Monitoring Program (AMP) collected similar concentration and flow data throughout the year from the Sacramento River about ten miles upstream of Greene's Landing (Larry Walker & Associates, 1996). Many of the relationships between flow, TSS, and metals were not significant (Tables 12-14), indicating the relationships reported during winter flows do not hold true at other times of the year.

Metal Source Study

A special study was undertaken from 11 March to 13 March 1995 to track riverine sources of metal into the Delta. Briefly, samples were collected from 26 stations ranging from 12 Sacramento River stations downstream of Shasta Dam, three western valley sources (i.e., Putah Creek, Cache Creek, and Skag Slough), four major river inputs (i.e., Feather, American, Mokelumne, and San Joaquin), and the Yolo and Sutter Bypass (Fig. 2; Appendix A). The samples were collected during the largest storm of the year when combined outflows from the basin peaked on 13 March at 297,000 CFS (Fig. 56).

Results from this study characterize a temporal period when the basin is rapidly filling with water (Table 15). Discharges from Shasta Dam on 10 March was approximately 9800 CFS (Table 15). Flows increased downstream of the Shasta Dam and peaked at 129,000 CFS at the Ord Ferry Bridge. Over approximately the next 80 river miles flows decreased reaching 42,000 CFS at the City of Colusa where a weir diverts water into the Sutter Bypass. The majority of river volume originated between Bend and Woodsen Bridge. Sources of water in this region would include several undammed creeks including Springs, Reeds, Red Bank, Elder, Paynes, Antelope, and Mill.

Total metal concentrations on the upper Sacramento River peaked at Cottonwood Creek which carries metal laden water from several abandoned mines (Table 15). From this point, concentrations decreased to Bend Bridge with the associated increased river volume. However, concentrations increased again at Road a-8 which is near the input of many of the undammed creeks mentioned above. These data indicate the undammed creeks may be an important source of metal enrichment in the river during high flow years. Concentrations of all metals measured except nickel decreased downstream from Road a-8 then increased again at the Colusa Bridge station where values were close to the those at Road a-8. This again points to undammed creeks, such as Deer and Big Chico, as potential sources for metal enrichment.

These findings are consistent with conclusion from other metal studies on the Sacramento River (Alpers pers. comm.; Larry Walker & Associates, 1997; Foe and Croyle, 1998). Larry Walker & Associates (1997) reported the largest loads of mercury in the Sacramento River occurred during storm events and originated from above the Feather River. Alpers conducted a study of metals during both wet and dry weather and consistently noted an increase in mercury load in the Sacramento River between Redding and Colusa. However, neither study identified the source(s). In addition, it is not clear from these studies if other metals are enriched along this stretch of river. To address this question, one must compare the results of this study with those of Foe and Croyle (1998). Samples for both studies were collected at the same time for the metals source components. Mercury followed the same pattern in upper Sacramento River, with enrichment between Bend Bridge and Ord Ferry (Foe and Croyle, 1998). Detailed follow-up studies are needed to identify the major source(s) of these metals along this stretch of river. During high flow conditions, a weir is opened on the Sacramento River near the Colusa station. River water enters the Sutter Bypass which eventually drains into the Yolo Bypass. Samples collected from the Sutter Bypass downstream of the Colusa station had greatly reduced metal concentrations, suggesting a dilution effect or settling (Table 15). However, Sacramento Slough which runs parallel to the Bypass had concentrations as high as those measured in Cottonwood Creek. Both the Sutter Bypass and Sacramento Slough are not well mixed at the sample stations during high flow events and can contain water from the Sacramento River, the Colusa Basin Drain, and several small creeks and Sloughs. The complex hydrology in the Sutter Bypass and Sacramento Slough during high flows makes interpretation of metal concentrations at these stations difficult.

Several stations which discharge into the Yolo Bypass, and eventually the north Delta, were monitored for total metals. Cache Creek was sampled a short distance upstream of where it, discharges into the Bypass. Concentrations of all metals were 150% to approximately 300% higher than at Cottonwood Creek (Table 15). Concentrations in Putah Creek prior to discharging into the Bypass were much higher than most main river stations. The west and east side of the Yolo Bypass was monitored near Interstate 80 in the region receiving water from Cache Creek, Putah Creek, Colusa Basin Drain, the Sacramento River, and the Sutter Bypass. Concentrations on the East side were consistently higher than those on the West side, indicating the Bypass is not well mixed during such high flow events. Concentrations on the east side were by far the highest concentrations measured during this survey.

One station was selected to quantify metal concentrations entering the Delta from the San Joaquin River. Metal concentrations in the San Joaquin River at Vernalis were moderately high when compared to those in the upper Sacramento River and Yolo Bypass.

The pattern of total metal concentrations were quite different in the lower Sacramento River. The Feather and American Rivers are the primary tributaries which enter the Sacramento River in the lower watershed. Unlike the upper Sacramento River, metal concentrations were much lower (Table 15). Water from the Sacramento River above the Feather and American Rivers begins to enter the Yolo Bypass when flows exceed 60,000 CFS. All additional water in the river is diverted into the Bypass when flows reach 100,000 CFS. The combined discharges of the Feather and American River was approximately 112,000 CFS on 11 March. Therefore, most of the water reaching Greene's Landing during this study is expected to have come from these two watersheds while most water in the upper Sacramento River would flow into the Bypass. For reasons which are unclear, metal concentrations at Greene's Landing were greater than those in the Feather and American Rivers, indicating that an additional source of metals must have been present. As stated above, there are no additional major sources at Greene's Landing during such high flows.

WATER QUALITY OBJECTIVES

Dissolved metal concentrations were compared to the USEPA National Ambient Water Quality Criteria and the USEPA Proposed California Toxics Rule Criteria to determine if water quality objectives were exceeded in samples collected from 15 stations during WY94 and WY95 (Tables 16-30). With the exception of As, criteria for the metals quantified in this study are water hardness dependent. In summary, water quality objectives to protect aquatic life were never exceeded for 549 individual metal analyses (Table 31).

Water quality criteria applied in this study are based on dissolved metal concentrations which were not measured at all stations during this study. For example, stations in the metals source study lacked dissolved metal analyses. These stations had among the highest total recoverable metal concentrations for the entire data set. Dissolved concentrations at these stations would be expected to be high, and may have exceeded the highest levels measured in the Delta study. If so, water quality criteria could have been exceeded.

TOXICITY ASSESSMENT

Waters sampled from the Delta region were tested for toxicity during WY94 and WY95 using the EPA Three Species Tests to determine if aquatic life was impacted. Deanovic *et al.*, (1996) and Deanovic *et al.*, (1998) contain a full description of the results. In brief, 34 and 58 toxic events were detected during WY94 and WY95, respectively (Table 32 & 33).

Approximately 7% of the samples tested toxic to *Ceriodaphnia* during WY94, while samples were toxic 14% of the time during WY95. Most of the toxicity (e.g., 68%) to *Ceriodaphnia* occurred in samples collected from back-sloughs and small upland drainages. Toxicity

Identification Evaluations were performed on toxic samples during both years to determine if the cause of toxicity could be determined. Typically, toxicity was related to pesticides, including organophosphates, carbamates, and unknown metabolically activated compounds. Metals were never implicated in TIE studies conducted on the toxic samples (Table 32 & 33). However, TIEs were not performed on all toxic samples due to budgetary limitations.

On 329 occasions *Selenastrum* toxicity tests were performed on samples collected from WY94 to WY95. The number of toxic events increased from less than 1% of the samples in WY94 to nearly 30% in WY95 (Table 32 & 33). As with *Ceriodaphnia*, the majority of the toxic events occurred in the back-sloughs and small upland drainages (Table 33). TIE tests on the toxic samples implicated non-polar organics as causative toxicants and, as with the *Ceriodaphnia* TIEs, no examples of metal related toxicity were found.

Pimephales toxicity tests were conducted on 216 occasions, with the bulk of the testing during WY94 (Table 32). Approximately 9% of the samples were toxic in WY94 with toxicity in all water categories except urban runoff receiving waters. No TIEs were conducted on these samples so the causative agents remain unknown but comparison of measured metal concentrations with fish EC_{50}'s suggest metals were not high enough to cause the observed toxicity.

The EPA Three Species are not necessarily the most sensitive organisms to metals. To address this issue, data was compiled for metals monitored in the study to determine if effect levels reported in the literature were exceeded (Reyes, 1994; Table 34). Tables were created documenting the most sensitive 15 literature reports for algae, invertebrates, and fish. Dissolved metal concentrations were selected as this is the most bioavailable to aquatic organisms.

The maximum dissolved concentration of copper measured in this study was 9.48 ppb (at Greene's Landing; hardness = 62 mg/l) which has been shown to have effects on invertebrates and algae (Reyes, 1994; Table 34). This concentration was lethal to several species of water flea for exposures down to two days. Algal responses ranged from altered photosynthetic output, decreased growth, and altered metabolism. No effects in freshwater fish would be expected based upon the most sensitive literature values.

The highest dissolved zinc concentration measured during monitoring was 70.2 ppb (at 5-mile; hardness = 80 mg/l) (Table 34). According to Reyes (1994), fish did not respond to zinc until dissolved concentrations exceeded the parts per million range. Similar levels are necessary to obtain a response in invertebrates. Algae, on the other hand, exhibit population declines (as measured by declines in cell numbers) down to 5 ppb. This concentration is slightly above the mean concentration when both water years were averaged. Exposures of *Selenastrum* for seven days at 5 ppb, as opposed to the four day exposures in this study, resulted in inhibited cell growth.

Cadmium concentrations peaked at 0.55 ppb (at Greene's Landing; hardness = 72 mg/l) and averaged 0.3 ppb in this study (Table 34). Algal responses to cadmium occur in the low ppb range and do not extend down into the parts per trillion (ppt) range (Reyes, 1994). Fish, such as the rainbow trout, can have reduced survival down to 0.2 ppb. However, exposure durations of 18 months are required to obtain this response. Other potential effects include albinism in catfish at 0.5 ppb. Invertebrates, such as copepods and water fleas, could respond at these concentrations with increased mortality.

Dissoved lead peaked at 3.87 ppb (at 5-mile; hardness = 80 mg/l) and averaged 0.31 ppb over the combined water years (Table 34). No algal responses would be expected at these concentrations (Table 35). Unicellular invertebrates, such as ciliates, had reduced oxygen uptake after only four minutes exposure to 0.75 ppb lead (Table 36). Three-spine stickleback, a freshwater fish, had increased mortality in response to 0.2 ppb dissolved lead exposure for nearly five days (Table 37).

The average dissolved concentration of arsenic was 1.28 ppb and the highest concentration was 3.03 ppb (Table 34) (at 5-mile; hardness = 80 mg/l). Phytoplankton exhibited altered photosynthetic productivity following longterm exposure to 1.5 ppb arsenic, however exposure for 109 days at this concentration in the basin is highly unlikely (Table 38). Fifty percent of *Daphnia duplex* were immobilized following exposure to 0.5 ppb lead for as little as one day (Table 39). Fish did not respond to arsenic exposure until concentrations exceeded 25 ppb (Table 40).

Some of the potential responses of algae, invertebrates, and fish are unlikely due to the duration of exposure necessary to elicit a response. Furthermore, some of the dissolved metal was probably biologically unavailable because of organo-iron complexes. However, the peak dissolved concentrations of metals presented for this study are probably underestimated. For example, total recoverable metal concentrations measured during the metals source study were, by far, the highest measured during the three water years. No dissolved concentrations were measured during the source study. Based on the high total concentrations in the source study, one would predict higher maximum dissolved concentrations for the overall project than those presented in Table 34.

METAL LOADS

The objective of the metal loads component of this study were: (1) estimate loads on the mainstem Sacramento River from January to April during a critically dry and a wet year and determine how they vary with hydrological conditions; (2) determine the spatial partitioning of loads during a wet year when water enters the Delta from the Yolo Bypass and Sacramento River; and (3) track loads into the Delta during the largest storm of WY95. Load calculations were based on a regression relationship and/or the Average Concentration (AC) method (see methods) for the first two objectives. Load calculations were point estimates for the load tracking study because a one time analyses of metals was performed at each station.

Sacramento/San Joaquin River and Delta

Regression equations (model method) for flow versus total recoverable metals were significant for copper, zinc, chromium, lead, and nickel during WY94 but the equations were not significant for any metals during WY95 (Table 9 & 10). The WY94 regression models consistantly estimated lower loads at Greene's Landing during WY94 when compared to the AC method. When significant, the regression model approach was considered to be more robust because it tested for statistical fitness whereas the AC approach lacked statistical analyses. The load estimate for cadmium during the dry WY94 was the lowest of all metals, with 398 lbs. contributed to the Delta over the four month time period (Table 41). Zinc load was the highest of all metals, ranging from 40,985 to 61,790 lbs. depending upon the method selected.

Water years were compared using the regression model for WY94 and the the AC method for WY95. Increased flows and higher total metal concentrations for most metals combined to result in increases in metal loads ranging from 893% to 2091% (Table 41). This is somewhat of an invalid comparison because much of the water entering the Delta during WY95 was in the Bypass. When total loads into the Delta from the Sacramento River Watershed (i.e., Greene's Landing + Yolo Bypass) for WY95 are compared to WY94, percent increase in loads ranges from 816% for cadmium to 5,395% for chromium (Table 41 & 42). To put these percentages in the context of pounds of metals added to the Delta, cadmium loads increased from 398 lbs. in WY94 to 3250 lbs. in WY95 while nickel loads increased from 15,885 lbs. to 1,120, 307 lbs. Chromium loads also increased markedly from 11,796 lbs. to 636,414 pounds. These data indicate high flow years contribute significantly more metal loads to the Delta when compared to a critically dry year.

A similar approach was used to calculate loads using Sacramento County Ambient Monitoring Program (AMP) data collected during the same water years. The same pattern emerged when WY94 and WY95 were compared, but the magnitude of increased loads for WY95 was variable when compared to this study (Table 42). As with the metal concentration comparisons among these two studies, much of the difference can be attributed to when samples were collected. Samples frequency for this study was much greater than that of the AMP due to the programatic questions each study is addressing. The increased sample frequency in this study resulted in samples which were collected across a wider specturum of flow conditions which is important for accurate predictions of loads.

Metal loads were calculated for the Sacramento River and Yolo Bypass during high flow to characterize the contribution differences between these two sources of Delta water. Since the regression relationship between total metal and flows were not significant for WY95, comparisons between the two sources was based on the AC method. Bypass water carried between 48% and 81% of the total load of the measured metals whereas the Sacramento River contributed between 19% and 52% (Table 43). Combined loads for these two sources varied from 3250 lbs. of cadmium to 1,107,667 lbs. and 1,120,307 lbs. of zinc and nickel, respectively. Dividing loads by the number of days from January to April provides an estimate of the average daily load entering the Delta during high flow conditions. Average daily loads of cadmium, zinc, and nickel were estimated at 31 lbs., 10,582 lbs., and 10,735 lbs., respectively.

Intersting patterns developed when the load contributions were compared for the Sacramento River and Yolo Bypass. Foe and Croyle (1998) estimated the sediment load entering the Delta from the Sacramento River and the Bypass to be 1,300,000 (34%) and 2,500,000 (66%) metric tons, respectively, from January through April 1995. The percentages of copper and zinc from the two sources are nearly identical to those of sediment. The Bypass contributes 74% of the chromium as well. These three metals were significantly related to TSS during this water year (Table 10), indicating that they are either bound to sediment particles diverted into the Bypass or they bind to sediment sources within the Bypass. The bulk of nickel loads entering the Delta from the Sacramento River Watershed is carried in the Bypass as well, but this contribution has no relationship to sediment loads. Nickel is common in the geological deposits of the western valley and may simply be washed down the bypass from local sources. Lead, chromium, and arsenic loads are generally equal in the Bypass and Sacramento River.

Metal Source Study

Similar patterns determined for the matal analysis for the source study emerged for metal loads. The primary sources of metal load to the upper Sacramento River is Cottonwood Creek (Table 15). Additional significant sources of metal loads enter the river between Bend Bridge and the Ord Ferry Road Bridge, again point toward undammed creeks as sources along this stretch of river. Cache Creek contributed significant loads to the lower stretches of the watershed. In fact, Cache Creek loads exceeded those of Cottonwood Creek. These results confirm that Cache Creek is a major source of metals during high flow years. Although metal concentrations in Putah Creek were among the highest measured in the study, loads were relatively low due to low flows when compared to flows at other stations. These load estimates often exceeded the average daily loads entering the Delta during WY95 (Table 42 & 43).

Unfortunately, the picture of loads for this study is incomplete due to the lack of flows at many of the stations. However, data obtained from this study indicate major storm events can contribute significant metal loads to the river. Additional studies should be performed to identify sources of loads between Bend Bridge and the Ord Ferry Road Bridge. In addition, this study should be repeated over a wider temporal period and should include flow measurements at all station to better characterize loads into the system.

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SUMMARY OF RECOMMENDATIONS

1. Continue to rely on the metal analysis protocols and QA/QC guidelines implemented in this project for determining metal concentrations in the surface waters of the Central Valley

2. Repeat the metals source study on the Sacramento River from Shasta Dam to Greene's Landing and the Yolo Bypass during major rain events to better characterize metal loads in the system. Incorporate flow measurements at all stations where such studies are performed to permit calculations of loads.

3. Conduct a special study on the Sacramento River downstream from the Bend River Bridge to the Ord Ferry Bridge during major storm events to characterize the sources of increased flows, metal concentrations, and loads. Monitoring should include stations in undammed creeks including Springs, Reeds, Red Bank, Elder, Paynes, Antelope, and Mill. Dissolved metal concentrations should be measured as well to permit an assessment of water quality objective exceedances.

4. Conduct a special study on the Sacramento River downstream from County Road A-8 to Colusa during major storm events to characterize sources of enriched metal concentrations along this stretch of the Sacramento River. Samples should be collected from Big Chico and Mill Creeks which are sources of water to the river in this area. Dissolved metal concentrations should be measured as well to permit an assessment of water quality objective exceedances.

5. Additional studies should be performed during high flow years when the Yolo Bypass is operational to better characterize the source(s) of elevated metal concentrations at Greene's Landing reported in this study when compared to concentrations in the American and Feather River.

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Table 1. Sites and Dates of Sampling in the Delta and Lower Sacramento River Basin

Site Name	Date Sampled
5 Mile Sl	10/5/94
American R. Sac State	3/11/95
Antioch	7/19/93
Antioch	7/19/93
Antioch	4/27/94
Antioch	4/27/94
Antioch	4/27/94
Antioch	4/27/94
Antioch	11/4/94
Antioch	11/4/94
Cache Creek @ Road 102	3/11/95
Cache Creek @ Road 102	3/11/95
Cottonwood Creek	3/10/95
Cottonwood Creek	3/10/95
Duck Slough	5/10/94
Duck Slough	5/10/94
Duck Slough	7/12/94
Duck Slough	7/12/94
Duck Slough	8/9/94
Duck Slough	8/9/94
Duck Slough	9/2/94
Duck Slough	9/2/94
Duck Slough	9/2/94
Duck Slough	1/9/95
East Yolo bypass	3/10/95
Feather R. Highway 99	3/11/95
French Camp Slough	3/23/94
French Camp Slough	3/23/94
French Camp Slough	9/2/94
French Camp Slough	9/2/94
Grizzly Bay	2/5/95
Grizzly Bay	2/5/95
Sac. R. @ Hood	7/19/93
Sac. R. @ Hood	7/19/93
Sac. R. @ Hood	8/3/93
Sac. R. @ Hood	8/3/93
Sac. R. @ Hood	8/3/93
Sac. R. @ Hood	9/14/93
Sac. R. @ Hood	9/14/93
Sac. R. @ Hood	10/14/93
Sac. R. @ Hood	10/14/93
Sac. R. @ Hood	10/14/93
Sac. R. @ Hood	12/13/93
Sac. R. @ Hood	12/13/93
Sac. R. @ Hood	12/13/93
Sac. R. @ Hood	4/12/94
Sac. R. @ Hood	4/12/94
Sac. R. @ Hood	4/12/94
Sac. R. @ Hood	4/12/94
Sac. R. @ Hood	5/10/94
Sac. R. @ Hood	5/10/94
Sac. R. @ Hood	5/10/94
Little Cow Cr. Dersch Br.	3/10/95
Little Cow Cr. Dersch Br.	3/10/95
Martinez	2/5/95
Martinez	2/5/95
Martinez	2/5/95
Middle R. @ Bullfrog	7/7/93
Middle R. @ Bullfrog	7/7/93
Middle R. @ Bullfrog	8/17/93
Middle R. @ Bullfrog	8/17/93
Middle R. @ Bullfrog	10/29/93
Middle R. @ Bullfrog	10/29/93
Middle R. @ Bullfrog	1/11/94
Middle R. @ Bullfrog	1/11/94
Middle R. @ Bullfrog	1/11/94
Middle R. @ Bullfrog	4/27/94
Middle R. @ Bullfrog	4/27/94
Mokelumne River	8/3/93
Mokelumne River	8/3/93
Mokelumne River	9/14/93
Mokelumne River	9/14/93
Mokelumne River	9/14/93
Mokelumne River	10/14/93
Mokelumne River	10/14/93
Mokelumne River	4/12/94
Mokelumne River	4/12/94
Mokelumne River	5/10/94
Mokelumne River	5/10/94
Mokelumne River	7/21/94
Mokelumne River	7/21/94
Mokelumne River	7/21/94
Mokelumne River	7/21/94
Mokelumne River	10/19/94
Mokelumne River	12/13/94
Mokelumne River	12/13/94
Mokelumne River	12/13/94
Mokelumne River	3/11/95
Mokelumne River	3/11/95
Mokelumne River	3/22/95
Mokelumne River	3/22/95
Old River @ Tracy Blvd.	5/25/94
Old River @ Tracy Blvd.	5/25/94
Old River @ Tracy Blvd.	6/3/94
Old River @ Tracy Blvd.	6/3/94
Paradise Cut	4/30/94
Paradise Cut	5/10/94
Paradise Cut	5/10/94
Paradise Cut	5/25/94
Paradise Cut	5/25/94

Table 1 (cont). Sites and Dates of Sampling in the Delta and Lower Sacramento River Basin

Site Name	Date Sampled
Paradise Cut	6/3/94
Paradise Cut	6/3/94
Paradise Cut	7/12/94
Paradise Cut	7/12/94
Prospect Slough	7/12/94
Prospect Slough	7/12/94
Prospect Slough	8/9/94
Prospect Slough	8/9/94
Prospect Slough	9/2/94
Prospect Slough	9/2/94
Prospect Slough	9/2/94
Prospect Slough	1/10/95
Prospect Slough	1/10/95
Prospect Slough	1/11/95
Prospect Slough	1/12/95
Prospect Slough	1/13/95
Prospect Slough	1/14/95
Prospect Slough	1/15/95
Prospect Slough	1/15/95
Prospect Slough	1/17/95
Prospect Slough	1/18/95
Prospect Slough	1/22/95
Prospect Slough	1/23/95
Prospect Slough	1/25/95
Prospect Slough	1/25/95
Prospect Slough	1/26/95
Prospect Slough	1/26/95
Prospect Slough	1/27/95
Prospect Slough	1/28/95
Prospect Slough	1/28/95
Prospect Slough	1/31/95
Prospect Slough	2/3/95
Prospect Slough	2/6/95
Prospect Slough	2/10/95
Prospect Slough	2/14/95
Prospect Slough	2/17/95
Prospect Slough	2/28/95
Prospect Slough	3/21/95
S.J. River @ Pt. Antioch	10/29/93
S.J. River @ Pt. Antioch	10/29/93
S.J. River @ Pt. Antioch	10/29/93
S.J. River @ Pt. Antioch	11/29/93
S.J. River @ Pt. Antioch	1/10/94
S.J. River @ Pt. Antioch	1/10/94
Putah Creek @ Mace Blvd	3/10/95
Sac River @ Rio Vista	7/20/93
Sac River @ Rio Vista	7/20/93
Sac River @ Rio Vista	7/20/93
Sac River @ Rio Vista	8/3/93
Sac River @ Rio Vista	8/3/93
Sac River @ Rio Vista	9/14/93
Sac River @ Rio Vista	9/14/93

Site Name	Date Sampled
Sac River @ Rio Vista	9/14/93
Sac River @ Rio Vista	10/14/93
Sac River @ Rio Vista	10/14/93
Sac River @ Rio Vista	12/13/93
Sac River @ Rio Vista	12/13/93
Sac River @ Rio Vista	4/12/94
Sac River @ Rio Vista	4/12/94
Sac River @ Rio Vista	5/10/94
Sac R. @ Shasta Dam	3/10/95
Sac R. @ Balls Ferry Br.	3/10/95
Sac R. @ Bend Bridge	3/10/95
Sac R. @ Colusa Bridge	3/10/95
Sac R. @ Cypress Bridge	3/10/95
Sac R. @ Old Ferry	3/10/95
Sac R. @ Road a-1	3/10/95
Sac R. @ Road a-9	3/10/95
Sacramento Slough	3/10/95
Skag Slough	1/22/95
Skag Slough	1/23/95
Skag Slough	1/28/95
Skag Slough	2/14/95
Skag Slough	3/10/95
S.J. River @ Stockton	10/29/93
S.J. River @ Stockton	10/29/93
S.J. River @ Stockton	10/29/93
S.J. River @ Stockton	11/29/93
S.J. River @ Stockton	1/10/94
S.J. River @ Stockton	1/10/94
S.J. River @ Stockton	1/10/94
S.J. River @ Stockton	4/27/94
S.J. River @ Stockton	4/27/94
Sutter Bypass	3/13/95
Sycamore	3/13/95
Ulatis Creek	3/23/94
Ulatis Creek	3/23/94
Ulatis Creek	12/13/94
Ulatis Creek	12/13/94
S.J. River @ Vernalis	7/7/93
S.J. River @ Vernalis	7/7/93
S.J. River @ Vernalis	8/17/93
S.J. River @ Vernalis	8/17/93
S.J. River @ Vernalis	10/29/93
S.J. River @ Vernalis	10/29/93
S.J. River @ Vernalis	1/11/94
S.J. River @ Vernalis	1/11/94
S.J. River @ Vernalis	1/11/94
S.J. River @ Vernalis	4/27/94
S.J. River @ Vernalis	4/27/94
S.J. River @ Vernalis	4/27/94
S.J. River @ Vernalis	4/27/94
S.J. River @ Vernalis	4/27/94
S.J. River @ Vernalis	3/11/95

Table 1 (cont). Sites and Dates of Sampling in the Delta and Lower Sacramento River Basin

Site Name	Date Sampled
S.J. River @ Vernalis	3/22/95
S.J. River @ Vernalis	
S.J. River @ Vernalis	
Victoria island	1/9/95
West Yolo bypass	3/10/95

Table 2. Summary of field blanks (18 megaohm deionized water) run through field sampling equipment at various sampling sites. Values are expressed as µg/l (ppb). Italics represent dissolved concentrations and normal font represent total recoverable concentrations.

#	Cu	Zn	Cr	Pb	Cd	Ni	As
1	*nd*	*0.04*	*nd*	*nd*	*0.011*	*0.25*	
2	0.16	0.16	nd	nd	nd	nd	
3	nd	nd	nd	nd	nd	nd	
4	0.02	0.599	0.09	nd	nd	0.18	nd
5	<.05	0.01	<.05	<.02	<.002	<.02	

D-042675

D-042676

Table 3. Percent Difference Between Duplicate Analyses for Total and Dissolved Concentrations of Six Metals in Field Samples Collected from the Sacramento/San Joaquin Delta Estuary

Sample	Metal Species						
	Cu	**Zn**	**Cr**	**Pb**	**Cd**	**Ni**	**As**
bp1	9	4	5	14	10	4	45
bp3/bp32	5	8	3	8	14	1	35
bp10/bp11	11	14	12	13	18	21	20
bp15/bp16	15	20	14	21	9	13	15
112cf	11	26	11	15	28	22	6
541	15	36	11	16	50	20	14
380/381	1	27	1	4	23	18	20
aa25a/aa25b	*9*	*2*	*31*	*0*	*53*	*6*	*25*
aa26a/aa26b	7	16	21	17	8	7	21
bp51	20	0	1	22	8	18	
bp54	24	18	11	31	9	2	
bp61/bp62	13	1	2	41	3	5	
bp63/bp64	*32*	*31*	*5*	*47*	*15*	*43*	
cf604/cf605	4	28	2	34	12	6	
cf624a/cf624b	*18*	*24*	*9*	*44*	*14*	*20*	
cf701A/cf701B	18	21	12	40	30	12	
cf702A/cf702B	*2*	*12*	*3*	*38*	*40*	*4*	
bp102	5	20	24	10	30	19	
bp106	12	20	26	7	15	22	
bp109	14	15	14	4	37	0	
cf801	10	61	38	32	50	54	
cf809	10	27	7	32	12	30	
Mean %	11	19	12	23	19	15	22
SD	7	14	10	14	15	14	11

Italics represent analysis for dissolved metals while normal font represent analysis for total metals

D—042676

Table 4. Summary of laboratory blanks (18 megaohm deionized water) run through field sampling equipment. Values are expressed as µg/l (ppb). Italics represent dissolved concentration and normal font represent total recoverable concentration.

#	Cu	Zn	Cr	Pb	Cd	Ni	As
1	nd	0.05	nd	nd	nd	0.02	nd
2	0.13	0.22	<.01	0.03	0.002	0.04	<.03
3	nd	0.04	nd	nd	nd	nd	0.12
4	*nd*	*0.39*	*nd*	*nd*	*0.009*	*0.24*	
5	nd	0.14	nd	nd	nd	nd	
6	0.18	1.81	0.2	nd	0.008	0.91	
7	nd	nd	nd	nd	nd	nd	

D-042677

Table 5. Summary of toxicity study blanks (deionized water) analyzed to assess potential addition of metals via filtration. Filtered treatments were passed through a through 0.45 μm filter. Values are expressed as μg/l (ppb).

#	Cu	Zn	Cr	Pb	Cd	Ni	As
1 Unfiltered	0.09	0.2	nd	nd	nd	nd	0.18
1 Filtered	0.06	0.36	nd	nd	nd	nd	0.18
2 Unfiltered	nd	0.08	nd	nd	0.01	0.11	0.14
2 Filtered	0.02	0.28	nd	0.06	nd	nd	nd
3 Unfiltered	nd	0.84	nd	nd	0.009	nd	
3 Filtered	nd	0.26	nd	nd	nd	nd	

D—042678

Table 6. Analytical information for four programs monitoring metals in the Sacramento River Watershed

	Monitoring Program				
	Ambient Monitoring Program	**SRCSD Waste Water Treatment Plant**	**Iron Mountain Mine Monitoring Program**		**BPTCP**
Metal Detection Limits (µg/l)	*(7/94-6/95)*		USBR: @ treatment plant	CVRWQCB	
As	1	0.05	*NS*	NS	0.1
Cd	0.03	0.01	*5-10*	0.1	0.002
Cr	1	0.05 - 0.1	*NS*	NS	0.05
Cu	0.05	0.05	*20-40*	1	0.04
Ni	1	0.05 - 0.15	*NS*	NS	0.1
Pb	0.1	0.1	*NS*	NS	0.01
Zn	4	0.2 - 0.5	*20-40*	3	0.02
Analytical Lab	ToxScan Laboratory	Frontier Geoscience		CH2M Hill*; Quality Analytical Labs, Inc.#	Moss Landing Mussel Watch
Method	*All EPA methods - check instrumentation*	Variable - see reports			Evapo-concentration & AA Spectrophotometer

D—042679

Table 6 (cont). Analytical information for four programs monitoring metals in the Sacramento River Watershed

	Monitoring Program				
	Ambient Monitoring Program	**SRCSD Waste Water Treatment Plant**	**Iron Mountain Mine Monitoring Program**		**BPTCP**
Sample Method	*pumped cross-sectional composite and 24-hour time-composite*	24-hour composite		grab	Acid cleaned CPE tubing and peristaltic pump
Total or total recoverable					Total recoverable
How non-detect data handled	*Parameters include only those detected ≥35% of the time*				
Citation	1	2	3	3	4

NS = not sampled
*= x/xx to 6/93
# = 7/93 - present
1 = Larry Walker Associates. 1996. Sacramento Coordinated Water Quality Monitoring Program 1995 Annual Report
2 =
3 = Heiman, D. 1987-199?. Iron Mountain Mine
4 = Goetzl, J. and M. Stephenson. 1993. Metals Implementation Project: Metals Monitoring of Central Valley Reservoir Releases: 1991-1992

D-042680

Table 7. Total and Dissolved Metal Concentrations (µg/l) in Samples Collected from All Stations Monitored during water years 1993, 1994, and 1995.

	Total Cu	Dis. Cu	Total Zn	Dis. Zn	Total Cr	Dis. Cr	Total Pb	Dis. Pb	Total Cd	Dis. Cd	Total Ni	Dis. Ni	Total As	Dis. As
1993														
Mean	5.56	1.83	9.61	1.94	4.65	0.60	2.81	0.11	0.06	0.02	6.90	1.37		
SD	5.85	0.58	6.56	1.10	6.07	0.36	8.88	0.07	0.10	0.01	8.83	0.85		
Max.	28.3	2.91	26.8	5.02	26.8	1.42	39.4	0.26	0.456	0.03	38.8	4.15		
Min.	1.98	0.32	4.12	0.7	0.007	0.09	0.2	0.03	0.007	0.009	0.75	0.31		
1994														
Mean	4.54	2.45	10.03	3.40	3.71	1.00	0.97	0.24	0.09	0.04	5.39	1.97	1.72	1.38
SD	3.11	1.32	8.21	2.79	4.79	1.20	1.42	0.26	0.14	0.08	6.94	1.71	0.91	0.61
Max.	14.9	9.48	39	18.5	23.1	5.39	8.98	1.38	0.74	0.55	35.8	8.52	3.98	2.4
Min.	0.75	0.2	0.08	0.16	0.19	0.06	0.01	0.01	0.006	0.001	0.52	0.13	0.11	0.24
1995														
Mean	21.20	3.48	57.61	7.74	33.76	2.45	5.82	0.55	0.13	0.03	63.50	5.02	1.49	1.19
SD	31.77	0.95	75.23	11.20	63.37	1.18	8.03	0.59	0.13	0.02	141.17	4.50	0.83	0.49
Max.	162	5.4	333	70.2	312	4.78	41.2	3.87	0.568	0.11	653	26	4.41	3.03
Min.	1.15	1.84	3.2	1.98	0.73	0.39	0.28	0.09	0.012	0.002	0.83	1.33	0.3	0.13

Table 8. Total and Dissolved Metal Concentrations (μg/l) in Samples Collected at Greene's Landing from January Through March of 1993, 1994, and 1995.

	Total Cu	Dis. Cu	Total Zn	Dis. Zn	Total Cr	Dis. Cr	Total Pb	Dis. Pb	Total Cd	Dis. Cd	Total Ni	Dis. Ni	Total As	Dis. As
1993														
Mean	3.92	2.91	6.20	2.10	1.54	0.29	0.29	0.08	0.05	0.03	1.85	0.75		
SD	0.41		0.14		0.88		0.12		0.01		0.36			
Max.	4.21	2.91	6.3	2.1	2.16	0.29	0.37	0.08	0.05	0.03	2.1	0.75		
Min.	3.63	2.91	6.1	2.1	0.92	0.29	0.2	0.08	0.04	0.03	1.59	0.75		
n=	2	1	2	1	2	1	2	1	2	1	2	1		
1994														
Mean	5.08	2.93	12.35	4.53	3.57	1.15	0.79	0.25	0.17	0.05	4.83	1.87		
SD	3.05	1.70	9.01	3.29	3.30	0.81	0.50	0.15	0.19	0.12	4.36	1.05		
Max.	14.29	9.48	39	18.5	14.9	3.78	2.15	0.53	0.74	0.55	19.5	4.62		
Min.	1.29	1.32	0.11	1.4	0.26	0.31	0.01	0.01	0.01	0.01	0.52	0.64		
n=	46	30	49	30	46	30	48	29	48	27	46	30		
1995														
Mean	8.64	3.44	23.68	5.63	9.34	2.76	3.27	0.51	0.10	0.03	12.10	5.51	1.25	1.09
SD	5.40	0.82	17.16	3.93	6.17	1.03	4.39	0.22	0.08	0.02	6.95	5.20	0.58	0.22
Max.	28.4	5.05	71.8	22.4	29	4.78	28.7	0.99	0.474	0.11	28.3	26	2.97	1.41
Min.	2.76	1.89	3.98	1.98	1.67	1.28	0.39	0.18	0.027	0.002	2.71	2.15	0.3	0.45
n=	47	27	37	27	47	27	47	27	47	27	47	27	24	20

Table 9. BPTCP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water year 1994

1993-1994	Cu	Zn	Cr	Pb	Cd	Ni	As
Total vs. Diss.	n=36 r2 = 0.32	n=36 r2 = 0.11	n=31 r2 = 0.55*	n=33 r2 = 0.46*	n=38 r2 = 0.12	n=37 r2 = 0.29	n=1 r2 = 0.014
Total vs. Flow	n=56 r2 = 0.56*	n=63 r2 = 0.52*	n=54 r2 = 0.64*	n=58 r2 = 0.58*	n=58 r2 = 0.027	n=56 r2 = 0.6*	
Diss. vs. Flow	n=47 r2 = 0.3*	n=46 r2 = 0.24	n=41 r2 = 0.34*	n=43 r2 = 0.12	n=45 r2 = 0.11	n=46 r2 = 0.37*	
Total vs. TSS	n=30 r2 = 0.7*	n=32 r2 = 0.64*	n=29 r2 = 0.72*	n=29 r2 = 0.61*	n=30 r2 = 0.023	n=29 r2 = 0.72*	
Diss. vs TSS	n=31 r2 = 0.1	n=32 r2 = 0.065	n=27 r2 = 0.047	n=27 r2 = 0.25	n=30 r2 = 0.015	n=29 r2 = 0.14	

* = significant relationship at $p<0.05$

Table 10. BPTCP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water year 1995

1994-1995	**Cu**	**Zn**	**Cr**	**Pb**	**Cd**	**Ni**	**As**
Total vs. Diss.	n= 26 r2 = 0.59*	n= 26 r2 =0.022	n=26 r2 = 0.37	n= 26 r2 = 0.41*	n= 31 r2 = 0.029	n=29 r2 = 0.099	n=17 r2 =0.004
Total vs. Flow	n=51 r2 = 0.12	n= 39 r2 = 0.06	n= 51 r2 = 0.18	n=49 r2 = 0.0054	n= 50 r2 = 0.077	n=52 r2 =0.23	n= 24 r2 = 0.042
Diss. vs. Flow	n= 28 r2 = 0.0026	n= 27 r2 = 0.011	n=27 r2 =0.14	n=26 r2 = 0.0000069	n= 33 r2 =0.016	n= 29 r2 = 0.051	n= 19 r2 =0.00082
Total vs. TSS	n=31 r2 =0.85*	n= 30 r2 =0.52*	n=31 r2 =0.78*	n= 29 r2 =0.16	n= 30 r2 =0.92*	n=31 r2 =0.081	n=21 r2 = 0.0013
Diss. vs TSS	n=23 r2 = 0.43*	n= 22 r2 = 0.000051	n=22 r2 = 0.12	n=21 r2 =0.47*	n= 28 r2 = 0.0087	n=23 r2 = 0.0042	n= 16 r2 =0.012

* = significant relationship at p<0.05

D-042684

D-042684

Table 11. BPTCP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water years 1993 and 1995 combined

1993-1995	Cu	Zn	Cr	Pb	Cd	Ni	As
Total vs. Diss.	n= 62 r2 = 0.32*	n=62 r2 =0.11	n=57 r2 = 0.55*	n=59 r2 = 0.46*	n=69 r2 =0.12	n=66 r2 = 0.29*	n=18 r2 = 0.014
Total vs. Flow	n= 107 r2 = 0.26*	n= 102 r2 = 0.24*	n=105 r2 =0.38*	n= 107 r2 = 0.15	n=108 r2 =0.018	n=108 r2 = 0.45*	n=25 r2 =0.063
Diss. vs. Flow	n=75 r2 = 0.11	n= 73 r2 = 0.078	n= 68 r2 = 0.58*	n=69 r2 =0.32*	n= 78 r2 = 0.039	n= 75 r2 =0.28*	n=20 r2 = 0.14
Total vs. TSS	n= 61 r2 =0.83*	n=62 r2 =0.6*	n=60 r2 =0.81*	n=58 r2 =0.22	n=60 r2 =0.039	n=60 r2 = 0.3*	n=21 r2 = 0.0013
Diss. vs TSS	n=54 r2 =0.17	n=54 r2 =0.023	n= 49 r2 =0.28*	n=48 r2 =0.56*	n= 58 r2 =0.069	n=52 r2 =0.087	n=16 r2 =0.012

* = significant relationship at p<0.05

Table 12. AMP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water years 1994

1993-1994	Cu	Zn	Cr	Pb	Cd	Ni	As
Total vs. Diss.	n=31 r2 =0.45*	n= 31 r2 =0.048	n= 31 r2 =	n=31 r2 =0.039	n= 31 r2 = 0.67*	n= 25 r2 =0.45*	n=31 r2 =0.59*
Total vs. Flow	n=28 r2 = 0.22	n= 28 r2 = 0.27	n= 28 r2 = 0.033	n=28 r2 =0.046	n=28 r2 = 0.1	n=22 r2 =0.66*	n= 28 r2 = 0.05
Diss. vs. Flow	n= 28 r2 =0.00001	n=28 r2 =0.25	n= 28 r2 =	n=28 r2 =0.084	n= 28 r2 =0.017	n=22 r2 =0.46*	n=28 r2 = 0.34
Total vs. TSS	n=31 r2 =0.18	n= 31 r2 =0.32	n=31 r2 =0.0041	n= 31 r2 =0.01	n=31 r2 =.026	n= 25 r2 = 0.27	n=31 r2 =0.012
Diss. vs TSS	n=31 r2 =.025	n= 31 r2 =0.076	n= 31 r2 =	n=31 r2 =0.000039	n=31 r2 =0.086	n=25 r2 =0.1	n=31 r2 =0.19

* = significant relationship at $p<0.05$

D-042686

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Table 13. AMP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water years 1995

1994-1995	Cu	Zn	Cr	Pb	Cd	Ni	As
Total vs. Diss.	n=23 r2 =0.13	n=23 r2 =0.065	n=23 r2 =0.00029	n= 23 r2 =0.0012	n= 23 r2 =	55	n=23 r2 =0.41*
Total vs. Flow	n=22 r2 =0.15	n=22 r2 =0.00004	n=22 r2 = 0.18	n=22 r2 = 0.24	n=22 r2 = 0.019	n=11 r2 = 0.11	n=22 r2 = 0.26
Diss. vs. Flow	n=22 r2 = 0.037	n=22 r2 = 0.0056	n=22 r2 = 0.0096	n=22 r2 = 0.058	n=22 r2 =	n=11 r2 = 0.12	n=22 r2 = 0.6*
Total vs. TSS	n=23 r2 = 0.73*	n=23 r2 = 0.11	n=23 r2 = 0.5	n=23 r2 = 0.72*	n=23 r2 = 0.66*	n=12 r2 = 0.41	n=23 r2 = 0.0011
Diss. vs TSS	n=23 r2 = 0.093	n=23 r2 = 0.68*	n=23 r2 = 0.0097	n=23 r2 = 0.0003	n=23 r2 = 5X10(-16)	n=12 r2 =0.22	n=23 r2 =0.095

* = significant relationship at $p<0.05$

D—042687

D-042688

Table 14. AMP: Summary of regression coefficients for total and dissolved metals, flow, and TSS during water years 1992 to 1996 combined

1992-1996	Cu	Zn	Cr	Pb	Cd	Ni	As
Total vs. Diss.	n=65 r2 = 0.35*	n= 65 r2 =0.034	n= 61 r2 = 0.012	n= 65 r2 = 0.041	n=65 r2 = 0.41*	n= 44 r2 = 0.13	n= 59 r2 = 0.53*
Total vs. Flow	n=58 r2 =0.27*	n=58 r2 = 0.0026	n=58 r2 = 0.25	n=58 r2 =0.31*	n=58 r2 =0.073	n=39 r2 =0.3	n=55 r2 =0.13
Diss. vs. Flow	n=58 r2 =0.0015	n=58 r2 =0.037	n=55 r2 =0.019	n=58 r2 =0.0015	2n=58 r2 =0.0092	n=38 r2 =0.13	n=55 r2 =0.35*
Total vs. TSS	n= 65 r2 =0.52*	n= 65 r2 =0.14	n= 65 r2 =0.44*	n= 65 r2 =0.56*	n= 65 r2 =0.2	n= 45 r2 =0.28	n= 61 r2 =0.00051
Diss. vs TSS	n=65 r2 =0.16	n=65 r2 =0.18	n=61 r2 =0.0013	n=65 r2 =0.0022	n= 65 r2 =0.041	n= 44 r2 =0.086	n= 61 r2 =0.038

* = significant relationship at p<0.05

D-042688

Table 15. Metal Sources to the Sacramento/San Joaquin Delta Estuary during March 1998

Date	Hour	Station #	Station Name	Flow (cfs)	Total Cu	Cu Load	Total Zn	Zn Load	Total Cr	Cr Load
3/10/95	800	bp103	Sac. River @ Shasta Dam	9800	1.23	29.47	4.6	110.22	1.44	34.50
3/10/95	1000	bp97	Sac. River @ Cypress Br.	18000	8.23	362.20	18.7	822.99	2.03	89.34
3/10/95	1115	bp106	Little Cow Creek @ Dersch Br.	10000	12.4	303.18	33	806.85	7.39	180.56
3/10/95	1230	bp104	Sac. River @ Balls Ferry Br.		10.7		29.6		6.5	
3/10/95	1330	bp102	Cottonwood Creek	12700	92.4	2869.16	170	5278.76	150	4657.73
3/10/95	1430	bp105	Sac. River @ bend Br.	55000	28.8	3872.88	68.8	9251.88	39.6	5325.21
3/10/95	1550	bp99	Sac. River @ Road a-8		70.4		157		150	
3/10/95	1700	bp107	Sac. River @ Road a-9	102132	56.6	14133.74	134	33461.51	99.6	24871.39
3/10/95	1830	bp98	Sac. River @ Ord Ferry	129000	46.8	14760.95	97.2	30657.37	75.7	23876.16
3/10/95	2000	bp100	Sac. River @ Colusa Br.	42000	58.1	5966.29	129	13247.01	94.8	9735.01
3/11/95	1630	bp111	Feather R. Highway 99	34500	4.54	382.96	6.29	530.58	3.14	264.87
3/11/95	1530	bp110	American R. @ Sac. State	77800	1.15	218.75	3.87	736.16	1.28	243.48
3/11/95	1300	CF 800	Sac. River @ Greens Landing	99000	8.6	2081.67	19.8	4792.69	13.8	3340.36
3/11/95	1500	CF 801	Mokelumne River		4.55		11.19		3.14	
3/13/95	1100	CF 803	Sutter Bypass		12		24.8		17.6	
3/10/95	2230	bp101	Sacramento Slough		73.2		173		122	
3/11/95	1200	bp109	Cache Creek @ Road 102	17500	140.5	6011.64	288.5	12344.19	291	12451.16
3/10/95	1240	bp108	Putah Creek @ Mace Blvd	682	76.9	128.23	253	421.87	98.4	164.08
3/10/95		bp114	East Yolo bypass		121		333		303	
3/10/95		bp113	West Yolo bypass		43		144		90	
3/10/95		bp112	Skag Slough		5.22		15.3		4.82	
3/11/95	1600	CF 802	Vernalis	7830	34.1	652.82	107	2048.45	69.1	1322.87

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Table 15 (cont). Metal Sources to the Sacramento/San Joaquin Delta Estuary during March 1998

Date	Hour	Station #	Station Name	Flow (cfs)	Total Pb	Pb Load	Total Cd	Cd Load	Total Ni	Ni Load
3/10/95	800	bp103	Sac. River @ Shasta Dam	9800	2.68	64.22	0.026	0.62	2.36	56.55
3/10/95	1000	bp97	Sac. River @ Cypress Br.	18000	0.83	36.53	0.11	4.84	2.3	101.22
3/10/95	1115	bp106	Little Cow Creek @ Dersch Br.	10000	6.9	168.71	0.114	2.79	7.09	173.35
3/10/95	1230	bp104	Sac. River @ Balls Ferry Br.		4.32		0.154		7.41	
3/10/95	1330	bp102	Cottonwood Creek	12700	19.9	617.92	0.353	10.96	211	6551.87
3/10/95	1430	bp105	Sac. River @ bend Br.	55000	7.68	1032.77	0.2	26.90	52	6992.70
3/10/95	1550	bp99	Sac. River @ Road a-8		15.7		0.371		492	
3/10/95	1700	bp107	Sac. River @ Road a-9	102132	12.9	3221.29	0.377	94.14	112	27967.83
3/10/95	1830	bp98	Sac. River @ Ord Ferry	129000	10.2	3217.13	0.296	93.36	251	79166.66
3/10/95	2000	bp100	Sac. River @ Colusa Br.	42000	12.1	1242.55	0.409	42.00	266	27315.54
3/11/95	1630	bp111	Feather R. Highway 99	34500	0.72	60.73	0.026	2.19	4.06	342.47
3/11/95	1530	bp110	American R. @ Sac. State	77800	0.44	83.70	0.017	3.23	2.17	412.78
3/11/95	1300	CF 800	Sac. River @ Greens Landing	99000	3.04	735.85	0.16	38.73	13.2	3195.13
3/11/95	1500	CF 801	Mokelumne River		3.93		0.05		4.17	
3/13/95	1100	CF 803	Sutter Bypass		4.88		0.068		20.4	
3/10/95	2230	bp101	Sacramento Slough		17.5		0.433		120	
3/11/95	1200	bp109	Cache Creek @ Road 102	17500	30.6	1309.30	0.403	17.24	652	27897.45
3/10/95	1240	bp108	Putah Creek @ Mace Blvd.	682	28	46.69	0.47	0.78	88.1	146.91
3/10/95		bp114	East Yolo bypass		33.3		0.438		600	
3/10/95		bp113	West Yolo bypass		15.6		0.311		165	
3/10/95		bp112	Skag Slough		4.66		0.057		14.1	
3/11/95	1600	CF 802	Vernalis	7830	17.6	336.94	0.169	3.24	128	2450.48

D—042690

D-042691

Table 16. Summary of Metal Concentration Data 1993-1994
San Joaquin River @ Antioch
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	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
DATE	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
7/19/93	2.22	4.65	9.2	7.2	2.06	9.98	85	96	0.78	4.09	145	0.01	0.03	0.86	1.9	78
10/29/93		2.72	37.0	29.0		4.99	340	380		1.34	550		0.01	2.90	6.2	626
10/29/93	2.73	1.72	37.0	29.0	3.18	1.68	340	380	2.62	0.19	550	0.02	0.02	2.90	6.2	626
11/29/93		2.69	37.0	29.0		2.3	340	380		1.86	550		0.02	2.90	6.2	616
1/10/94	3.82	3.68	25.9	20.4	2	10.5	236	267	0.12	3.35	392	0.04	0.02	2.10	4.6	262
4/27/94	2.71	4.72	16.4	13.0	1.46	7.06	151	170	0.81	3.27	254	0.01	0.03	1.42	3.1	154
4/27/94	2.75	4.85	16.4	13.0	1.23	6.48	151	170	0.63	2.82	254	0.02	0.03	1.42	3.1	154
11/4/94	2.19	3.69			2.97	7.23			0.71	2.31		0.01	0.01			no data

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
^ = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 1-hour average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042691

D-042692

Table 16. Summary of Metal Concentration Data 1993-1994
San Joaquin River @ Antioch

DATE	NICKEL				ARSENIC			SILVER			LEAD			HARDNESS
	D	T	O*	O#	D	T	O†	D	T	O^	D	T	O*#	
7/19/93	1.47	5.91	127	42					0.01	2.25	0.08	0.85	1.9	78
10/29/93		3.21	510	170								0.03	11	626
10/29/93	2.73	1.61	510	170							0.25		11	626
11/29/93		2.97	510	170					0.01	79		0.07	11	616
1/10/94	0.98	3.42	355	117					0	18	0.04	0.41	7.1	262
4/27/94	1.98	5.15	227	75							0.12	0.66	4.0	154
4/27/94	1.43	4.15	227	75							0.13	0.93	4.0	154
11/4/94	2.12	4.2			0.13	0.41	5	0	0.01		0.09	0.36		no data

D-042692

D-042693

Table 17. Summary of Metal Concentration Data 1994-1995
Duck Slough
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DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
5/10/94	4.9	12	11.2	8.8	7.76	26	103	116	5.39	18.7	175	0.01	0.07	1.02	2.2	98
7/12/94	4.41	12.6	8.6	6.8	7.17	32.3	79	89	4.78	19.6	136	0.04	0.08	0.81	1.8	72
8/9/94	4.52	12.5	8.2	6.4	6.75	27.5	75	85	5	22.4	130	0.01	0.07	0.78	1.7	68
9/2/94	-	13.5	8.4	6.6		29.6	77	87		23.1	133		0.07	0.79	1.7	70
9/2/94	3.58	14.9	8.4	6.6	4.56	30.7	77	87	4.08	21.9	133	0.02	0.06	0.79	1.7	70
1/9/95	3.39	-	23.5	18.5	2.75	-	215	243	2.41	-	357	0.02	-	1.93	4.2	234

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042693

Table 17. Summary of Metal Concentration Data 1994-1995
Duck Slough

DATE	NICKEL				ARSENIC			LEAD			HARDNESS
	D	T	O*	O#	D	T	O†	D	T	O*#	
5/10/94	8.52	24.1	155	51	1.09	2.06	5	1.05	3.3	2.5	98
7/12/94	6.85	28.8	119	39	1.32	1.58	5	0.88	4.28	1.8	72
8/9/94	8	31.4	113	38	2.05	2.4	5	1.38	8.98	1.6	68
9/2/94		35.8	116	38		2.21	5		8.56	1.7	70
9/2/94	5.16	34.3	116	38	2.17	3.98	5	1.08	7.39	1.7	70
1/9/95	6.35	-	323	107	-	-	5	0.37	-	6.3	234

D-042694

D-042694

Table 18. Summary of Metal Concentration Data 1994
French Camp Slough
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
3/23/94	2.83	2.72	5.6	4.4	3.59	9.24	52	59	0.81	4	91	0.01	0.04	0.56	1.2	44
9/2/94	2.94	6.17	9.6	7.6	2.27	13.3	88	100	0.99	3.64	151	0.01	0.04	0.89	1.9	82

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042695

D-042696

Table 18. Summary of Metal Concentration Data 1994
French Camp Slough

DATE	NICKEL				ARSENIC			LEAD			HARDNESS
	D	T	O*	O#	D	T	O†	D	T	O*#	
3/23/94	1.29	3.33	78	26	1.33	1.49	5	0.41	2.26	1.0	44
9/2/94	0.99	2.15	133	44	2.4	2.71	5	0.37	1.58	2.0	82

D-042696

D-042697

Table 19. Summary of Metal Concentration Data 1993-1994
Sacramento River @ Hood
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
7/19/93	1.42	3.6	6.1	4.8	1.12	6.46	56	63	0.32	2.85	98	nd	0.04	0.60	1.3	48
8/3/93	1.61	3.77	8.0	6.3	1.47	5.91	73	83	0.36	3.25	127	0.02	0.04	0.76	1.6	66
8/3/93		4.18	8.0	6.3		7.41	73	83		3.27	127		0.04	0.76	1.6	66
9/14/93	2	3.76	7.8	6.1	5.02	16	72	81	0.36	2.52	124	0.03	0.04	0.74	1.6	64
10/14/93	1.38	2.71	6.1	4.8	1.29	8.55	56	63	0.22	1.57	98	0.01	0.04	0.60	1.3	48
10/14/93	1.39		6.1	4.8	0.95		56	63	0.34		98	0.01		0.60	1.3	48
12/13/93		4.38	6.7	5.3		7.5	62	70		3.99	107		0.08	0.65	1.4	54
12/13/93	2.16	4.35	6.7	5.3	0.38	7.6	62	70	0.19	3.4	107	0.01	0.07	0.65	1.4	54
4/12/94	2.12	2.89	8.4	6.6	2.36	4.62	77	87	0.4	1.34	133	0.02	0.03	0.79	1.7	70
4/12/94	2.17	2.94	8.4	6.6	1.72	3.81	77	87	0.34	1.03	133	0.02	0.03	0.79	1.7	70
5/10/94		2.63	6.7	5.3		5.14	62	70		1.52	107		0.04	0.65	1.4	54
5/10/94	1.84	2.94	6.7	5.3	1.33	3.8	62	70	0.55	1.36	107	0.02	0.03	0.65	1.4	54

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
^ = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 1-hour average criteria)

D—042697

Table 19. Summary of Metal Concentration Data 1993-1994
Sacramento River @ Hood

DATE	NICKLEL				LEAD			SILVER			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O^	
7/19/93	0.7	4.19	84	28	0.06	2.85	1.1	0.003	0.01	0.98	48
8/3/93	0.84	4.3	111	37	0.05	0.61	1.6	0.004		1.69	66
8/3/93		4.81	111	37		0.53	1.6		0.01	1.69	66
9/14/93	0.96	3.76	108	36	0.03	0.3	1.5			1.60	64
10/14/93	0.63	2.3	84	28	nd	0.31	1.1			0.98	48
10/14/93	0.67		84	28	0.06		1.1			0.98	48
12/13/93		4.52	93	31		0.64	1.3	0.002	0.01	1.20	54
12/13/93	0.87	4.81	93	31	0.04	0.63	1.3			1.20	54
4/12/94	0.92	2.02	116	38	0.07	0.24	1.7			1.87	70
4/12/94	0.75	1.64	116	38	0.08	0.24	1.7			1.87	70
5/10/94		2.34	93	31		0.29	1.3			1.20	54
5/10/94	1	1.83	93	31	0.09	0.34	1.3			1.20	54

D-042699

Table 20. Summary of Metal Concentration Data 1993-1994
Middle River @ Bullfrog Landing
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
7/7/93	1.67	2.54	8.8	6.9	1.15	6.77	81	92	0.45	0.01	139		0.01	0.83	1.8	74
8/17/93	1.73	28.3	6.1	4.8	1.31	6.66	56	63	0.58	26.8	98		0.46	0.60	1.3	48
10/29/93	1.47	1.59	7.5	6.0	0.62	1.34	70	79	0.24	0.41	120	0.01	0.01	0.72	1.6	62
1/11/94		2.06	10.2	8.0		2.2	94	106		0.56	160		0.02	0.94	2.0	88
1/11/94	2.01	0.75	10.2	8.0	1.2	1.7	94	106	0.39	0.24	160	0.02	0.01	0.94	2.0	88
4/27/94	2.07	2.38	13.6	10.8	0.16	1.97	125	142	0.28	0.68	212	0.01	0.01	1.21	2.6	124

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
\# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
^ = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 1-hour average criteria)

D-042699

Table 20. Summary of Metal Concentration Data 1993-1994
Middle River @ Bullfrog Landing
Page 2 of 2

DATE	NICKEL				LEAD			SILVER			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O^	
7/7/93	1.04	2.62	122	40	0.1	0.46	1.8	0.01	0.01	2.06	74
8/17/93	1.22	38.8	84	28	0.22	39.4	1.1				48
10/29/93	0.71	1.07	105	35		0.13	1.5				62
1/11/94		2.16	141	47		0.11	2.2				88
1/11/94	1.52	0.84	141	47	0.06	0.03	2.2				88
4/27/94	1.41	1.98	189	62	0.06	0.16	3.2				124

D-042700

D-042701

Table 21. Summary of Metal Concentration Data 1994-1995
Mokelumne River
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
10/19/94		2.15				7.29				0.73			0.02			no data
7/21/94	1.25	2.01			5.65	5.32			0.16	0.72		0.02	0.02			no data
7/21/94	1.14	1.88			5.57	6.34			0.11	0.57		0.01	0.02			no data
8/3/93			4.7	3.7			44	50			77			0.48	1.1	36
8/3/93	1.62	1.98	4.7	3.7	2.49	6.15	44	50	0.09	0.66	77	0.01	0.02	0.48	1.1	36
9/14/93		3.19	4.3	3.4		4.84	40	45		1.08	70		0.03	0.44	1.0	32
9/14/93	1.6	2.8	4.3	3.4	3.16	4.12	40	45	0.09	1.51	70	0.01	0.03	0.44	1.0	32
10/14/93	1.37	1.77	3.4	2.6	1.24	3.37	31	35	0.11	0.54	55	0.01	0.02	0.36	0.8	24
4/12/94	1.29	2.21	4.3	3.4	0.75	4.2	40	45	0.2	1.49	70	0.01	0.01	0.44	1.0	32
5/10/94		2.42	4.1	3.2		4.51	38	43		0.94	66		0.01	0.42	0.9	30
5/10/94		2.05	4.1	3.2		2.91	38	43		1.06	66		0.01	0.42	0.9	30
12/13/94	1.84	3.97			4.1	52.8			0.72	3.54		0.01	0.02			no data
12/13/94	1.89				2				0.77			0.01				no data
3/11/95		4.31	3.1	2.5		16.1	29	33		2.41	52		0.07	0.34	0.7	22
3/11/95		4.79	3.1	2.5		6.27	29	33		3.86	52		0.03	0.34	0.7	22
3/22/95		4.26	4.7	3.7		18.2	44	50		2.1	77		0.1	0.48	1.1	36
3/22/95		4.72	4.7	3.7		13.3	44	50		1.93	77		0.08	0.48	1.1	36

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
^ = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 1-hour average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042701

D-042702

Table 21. Summary of Metal Concentration Data 1994-1995
Mokelumne River
Page 2 of 2

DATE	NICKEL				LEAD			SILVER			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O^	D	T	O†	
10/19/94		0.83				0.28								no data
7/21/94	0.44	0.68			0.08	0.3		0.01	0.01		0.6	0.5	5	no data
7/21/94	0.47	0.63			0.1	0.25					0.45	0.63	5	no data
8/3/93			66	22			0.8			0.60				36
8/3/93	0.31	0.75	66	22	0.08	0.3	0.8	nd	0	0.60				36
9/14/93		1.23	60	20		0.45	0.7							32
9/14/93	0.39	1.11	60	20	0.1	0.5	0.7							32
10/14/93	0.31	0.92	47	16	0.07	0.26	0.5							24
4/12/94	0.55	1.73	60	20	0.1	0.34	0.7							32
5/10/94		1.48	57	19		0.32	0.7					1.27	5	30
5/10/94		1.19	57	19		0.38	0.7					1.22	5	30
12/13/94	1.34	3.34			0.18	0.67								no data
12/13/94	1.33				0.18									no data
3/11/95		2.61	44	14		4.66	0.5							22
3/11/95		5.72	44	14		3.19	0.5							22
3/22/95		2.47	66	22		0.89	0.8							36
3/22/95		1.72	66	22		1.3	0.8							36

D-042702

D-042703

Table 22. Summary of Metal Concentration Data 1994-1995
Old River @ Tracy Blvd.

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
5/25/94	1.44	2.43	16.2	12.8	1.99	7.18	149	168	0.37	2.33	251	0.01	0.02	1.40	3.0	152
6/3/94	1.74	3.84	23.8	18.8	1.99	9.26	218	246	0.25	3.2	362	0.01	0.02	1.96	4.2	238

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† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042703

Table 22. Summary of Metal Concentration Data 1994-1995
Old River @ Tracy Blvd.

DATE	NICKEL				LEAD			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	
5/25/94	3.01	2.82	224	74	0.12	3.06	4.0	1	0.98	5	152
6/3/94	1	3.28	327	108	0.05	1.92	6.4	1.58	0.81	5	238

D-042704

Table 23. Summary of Metal Concentration Data 1994-1995
Paradise Cut
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
4/30/94	1.19		37	29	0.83		340	380	0.21		550	0.01		2.9	6.2	432
5/10/94	2.19	3.42	37	29	nd	4.86	335	379	0.06	2.13	549	0.01	0.02	2.8	6.2	396
5/25/94	1.01		37	29	2.07		337	380	0.25		550	0.01		2.9	6.2	398
5/25/94	1.81		37	29	1.43		337	380	0.08		550	nd		2.9	6.2	398
6/3/94	2.41	4.3	36	28	2.54	7.3	327	369	0.08	nd	536	0.01	0.02	2.8	6.0	384
7/12/94	0.2	4.88	37	29	3.55	8.95	338	380	0.2	4.72	550	0.01	0.03	2.9	6.2	400
7/12/94			37	29			338	380			550			2.9	6.2	400

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D—042705

Table 23. Summary of Metal Concentration Data 1994-1995
Paradise Cut

	NICKEL				LEAD			ARSENIC			HARDNESS
DATE	D	T	O*	O#	D	T	O*#	D	T	O†	
4/30/94	2.07		510	170	nd		11	1.24		5	432
5/10/94	1.83	3.79	504	167	nd	0.33	11	0.24	0.11	5	396
5/25/94	2.12		506	167	0.04		11	1.4		5	398
5/25/94	2.29		506	167	nd		11	1.34		5	398
6/3/94	2.38	4.75	491	162	0.07	0.64	10	1	1.74	5	384
7/12/94	2.16	8.59	508	168	0.05	0.6	11	2.27	3.15	5	400
7/12/94			508	168			11				400

D-042706

D-042707

Table 24. Summary of Metal Concentration Data 1994-1995
Prospect Slough

DATE	COPPER D	COPPER T	COPPER O*	COPPER O#	ZINC D	ZINC T	ZINC O*	ZINC O#	CHROMIUM (III) D	CHROMIUM (III) T	CHROMIUM (III) O*#	CADMIUM D	CADMIUM T	CADMIUM O*	CADMIUM O#	HARDNESS
7/12/94	3.52	8.29	9.8	7.7	6.83	16.6	90	102	3.06	10.8	155	0.02	0.04	0.91	2.0	84.3
8/9/94	4.1	7.7	8.6	6.8	4.03	12.1	79	89	3.83	11	136	0.02	0.03	0.81	1.8	72
9/2/94		8.16	10.0	7.9		13.3	92	104		9.58	157		0.04	0.92	2.0	86
9/2/94	4.22	8.49	10.0	7.9	3.97	12.2	92	104	3.52	9.84	157	0.02	0.03	0.92	2.0	86
1/10/95		124	9.6	7.6		270	88	100		242	151		0.57	0.89	1.9	82
1/10/95		162	9.6	7.6		328	88	100		271	151		0.52	0.89	1.9	82
1/11/95		86.9	10.2	8.0		172	94	106		168	160		0.23	0.94	2.0	88
1/12/95		34.4	7.5	6.0		66.3	70	79		57.6	120		0.18	0.72	1.6	62
1/13/95		17.9	7.1	5.6		42.4	66	74		32.7	114		0.16	0.69	1.5	58
1/14/95		40.3	9.6	7.6		84	88	100		58	151		0.22	0.89	1.9	82
1/15/95		29.8	7.3	5.8		128	68	77		42.3	117		0.2	0.71	1.5	60
1/15/95		28.9	7.3	5.8		128	68	77		42.5	117		0.2	0.71	1.5	60
1/17/95		19	6.1	4.8		78.9	56	63		27.1	98		0.09	0.60	1.3	48
1/18/95		24.3		no data		103		no data		32.9	no data		0.17			no data
1/22/95		13.3	7.8	6.1		26.3	72	81		18.7	124		0.09	0.74	1.6	64

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# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042707

D-042708

Table 24. Summary of Metal Concentration Data 1994-1995
Prospect Slough
Page 2 of 4

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
1/23/95		14.9	7.3	5.8		39.3	68	77		17.4	117		0.1	0.71	1.5	60
1/25/95	3.48	9.06	7.8	6.1	5.69	28.3	72	81	2.51	9.56	124	0.02	0.08	0.74	1.6	64
1/26/95	4.78	15	6.9	5.5	8.17	36.3	64	72	4.08	21.6	111	0.06	0.11	0.67	1.5	56
1/27/95		12.3	7.3	5.8		31.9	68	77		19.2	117		0.1	0.71	1.5	60
1/28/95	4.51	12.5	7.3	5.8	7.87	32.8	68	77	3.69	17.6	117	0.06	0.11	0.71	1.5	60
1/31/95		9.73	8.2	6.4		23.3	75	85		11.5	130		0.07	0.78	1.7	68
2/3/95		8.69	8.2	6.4		19.9	75	85		10	130		0.07	0.78	1.7	68
2/6/95		14.7	5.8	4.6		29.2	54	61		14.3	94		0.08	0.58	1.3	46
2/10/95		7.34	8.0	6.3			73	83		7.65	127		0.07	0.76	1.6	66
2/14/95		8.22	9.4	7.4			87	98		10.5	148		0.08	0.87	1.9	80
2/17/95		5.72	15.9	12.5			146	165		8.08	245		0.04	1.38	3.0	148
2/28/95		8.59	24.3	19.2			223	252		14.5	370		0.07	1.99	4.3	244
3/21/95		10	6.9	5.5		20.5	64	72		13.3	111		0.07	0.67	1.5	56

D-042708

Table 24. Summary of Metal Concentration Data 1994-1995
Prospect Slough

DATE	NICKEL D	NICKEL T	NICKEL O*	NICKEL O#	LEAD D	LEAD T	LEAD O*#	ARSENIC D	ARSENIC T	ARSENIC O†	HARDNESS
7/12/94	5.36	15.3	136	45	0.4	1.24	2.1	1	1.06	5	84.3
8/9/94	7.04	15.7	119	39	0.41	1.24	1.8	1.93	1.67	5	72
9/2/94		18.3	138	46		2.24	2.1		2.1	5	86
9/2/94	6.12	18.5	138	46	0.73	2.06	2.1	2.04	3.24	5	86
1/10/95		601	133	44		28.4	2.0		0.6	5	82
1/10/95		587	133	44		41.2	2.0			5	82
1/11/95		417	141	47		16	2.2		1.46	5	88
1/12/95		103	105	35		7.81	1.5		1.5	5	62
1/13/95		38	99	33		3.65	1.4		1.63	5	58
1/14/95		79.2	133	44		13.5	2.0		1.2	5	82
1/15/95		53.7	102	34		6.54	1.4		2.48	5	60
1/15/95		62.8	102	34		6.15	1.4		2.27	5	60
1/17/95		36.6	84	28		2.95	1.1		3.32	5	48
1/18/95		45.1		no data		4.82			4.41	5	no data
1/22/95		27.3	108	36		2.49	1.5		1.07	5	64

D-042709

Table 24. Summary of Metal Concentration Data 1994-1995
Prospect Slough

DATE	NICKEL				LEAD			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	
1/23/95		28.8	102	34		3	1.4		1.18	5	60
1/25/95	4.39	16.7	108	36	0.38	1.26	1.5	1.43	1.81	5	64
1/26/95	7.28	36.6	96	32	0.57	2.53	1.3	1.51	nd	5	56
1/27/95		28.3	102	34		2.07	1.4		1.48	5	60
1/28/95	6.75	29.3	102	34	0.57	2.11	1.4	1.45	0.99	5	60
1/31/95		14.8	113	38		1.45	1.6			5	68
2/3/95		13.5	113	38		1.12	1.6			5	68
2/6/95		21.3	81	27		1.95	1.1			5	46
2/10/95		11.4	111	37		0.76	1.6			5	66
2/14/95		15.8	130	43		4.2	2.0			5	80
2/17/95		13.8	219	72		0.75	3.8			5	148
2/28/95		28.3	334	111		1.93	6.5			5	244
3/21/95		19.3	96	32		3.45	1.3			5	56

D-042710
D-042710

Table 25. Summary of Metal Concentration Data 1993-1994
Sacramento River @ Rio Vista
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
7/20/93	1.56	3.51	5.6	4.4	1.31	6.96	52	59	0.41	2.63	91	0.01	0.04	0.56	1.2	44
7/20/93	1.45		5.6	4.4	0.7		52	59	0.5		91	0.02		0.56	1.2	44
8/3/93	2.4	3.17	7.8	6.1	2.64	4.55	72	81	1.14	2.06	124	0.02	0.03	0.74	1.6	64
9/14/93	1.97	2.98	7.8	6.1	1.4	6.08	72	81	0.56	2.11	124	0.02	0.04	0.74	1.6	64
9/14/93	1.86		7.8	6.1	0.88		72	81	0.59		124	0.01		0.74	1.6	64
10/14/93	1.91	3.48	6.9	5.5	2.64	12.5	64	72	0.3	2.36	111	0.03	0.04	0.67	1.5	56
12/13/93	1.58	2.97	9.0	7.1	0.71	4.6	83	94	0.72	1.56	142	0.01	0.03	0.84	1.8	76
4/12/94	1.88	2.98	9.0	7.1	1.06	4.02	83	94	0.37	1.77	142	0.02	0.02	0.84	1.8	76
5/10/94	1.9	2.97	7.5	6.0	1.75	5.07	70	79	0.52	2.05	120	0.02	0.03	0.72	1.6	62

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
^ = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 1-hour average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042711

Table 25. Summary of Metal Concentration Data 1993-1994
Sacramento River @ Rio Vista

DATE	NICKEL				LEAD			ARSENIC			SILVER			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	D	T	O^	
7/20/93	1.35	4.97	78	26	0.1	0.62	1.0				nd	0.01	0.84	44
7/20/93	1.02		78	26	0.08		1.0				<0.002		0.84	44
8/3/93	1.71	2.89	108	36	0.18	0.32	1.5				0.006	0.01	1.60	64
9/14/93	1.22	3.24	108	36	0.03	0.21	1.5					0.01	1.60	64
9/14/93	1.1		108	36	0.09		1.5				<0.002	nd	1.60	64
10/14/93	0.85	3.62	96	32	0.04	0.27	1.3				nd	0.01	1.27	56
12/13/93	0.87	2.88	125	41	0.04	0.36	1.9				0.002	0.01	2.15	76
4/12/94	1.21	2.99	125	41	0.08	0.26	1.9							76
5/10/94	1.43	3.45	105	35	0.09	0.29	1.5	1.9	2.2	5				62

D—042712

Table 26. Summary of Metal Concentration Data 1995
Skag Slough
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
1/22/95		11.9	12.9	10.2		26.3	119	134		22.7	201		0.07	1.15	2.5	116
1/23/95		14.6	13.6	10.8		45.6	125	142		24.3	212		0.07	1.21	2.6	124
1/28/95		13	11.7	9.3		30.3	108	122		20.1	184		0.12	1.06	2.3	104
2/14/95		3.89	19.8	15.6			182	205		5.74	304		0.03	1.67	3.6	192
3/10/95		5.22	22.3	17.6		15.3	204	230		4.82	340		0.06	1.85	4.0	220

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

D-042713

Table 26. Summary of Metal Concentration Data 1995
Skag Slough

	NICKEL				LEAD			ARSENIC			HARDNESS
DATE	D	T	O*	O#	D	T	O*#	D	T	O†	
1/22/95		33.9	178	59		2.52	3.0		2.54	5	116
1/23/95		41.9	189	62		3.9	3.2		3.08	5	124
1/28/95		37.2	162	54		2.19	2.6		1.48	5	104
2/14/95		11.1	273	90		0.5	5.1				192
3/10/95		14.1	306	101		4.66	5.9				220

D-042714

Table 27. Summary of Metal Concentration Data 1993-1994
San Joaquin River @ Stockton

	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
DATE	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
10/29/93		2.85	8.8	6.9		5.55	81	92		0.83	139		0.01	0.83	1.8	74
10/29/93	1.98	2.66	8.8	6.9	4.5	4.96	81	92	0.15	1.16	139	0.01	0.01	0.83	1.8	74
11/29/93		2.66	19.5	15.4		8.2	178	202		0.98	299		0.03	1.64	3.6	188
1/10/94		2.96	20.9	16.5		10.3	191	216		0.38	319		0.02	1.75	3.8	204
1/10/94	2.67	2.76	20.9	16.5	10	10.8	191	216	0.08	0.54	319		0.02	1.75	3.8	204
4/27/94	2.99	4.25	18.0	14.2	6.65	13	165	187	0.2	0.6	278	0.01	0.02	1.54	3.3	172

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)

D-042715

Table 27. Summary of Metal Concentration Data 1993-1994
San Joaquin River @ Stockton

DATE	NICKEL D	NICKEL T	NICKEL O*	NICKEL O#	LEAD D	LEAD T	LEAD O*#	HARDNESS
10/29/93		1.66	122	40		1.18	1.8	74
10/29/93	1.29	1.71	122	40	0.23	1.36	1.8	74
11/29/93		1.94	268	89		0.95	5.0	188
1/10/94		2.52	287	95		0.1	5.4	204
1/10/94	2.07	2.3	287	95		0.74	5.4	204
4/27/94	1.84	2.17	249	82	0.16	0.83	4.5	172

D-042716

D-042716

Table 28. Summary of Metal Concentration Data 1994
Ulatis Creek
Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
3/23/94	2.98	4.23	29.4	23.2	5.55	9.56	268	303	1.71	3.87	442	0.02	0.03	2.34	5.1	304
12/13/94	3.89	21.1			18.5	57.3			0.65	13.1		0.04	0.13			no data

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

Table 28. Summary of Metal Concentration Data 1994
Ulatis Creek

DATE	NICKEL				LEAD			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	
3/23/94	3.65	5.69	403	133	0.07	0.46	8.2	1.62	1.78	5	304
12/13/94	3.45	16.2			0.2	5.18		1.39	1.22	5	no data

D—042718

D-042719

Table 29. Summary of Metal Concentration Data 1993-1995

San Joaquin River at Vernalis

Page 1 of 2

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
7/7/93	1.63	6.38	15.7	12.4	1.52	16.1	144	163	0.63	8.38	243		0.02	1.36	3.0	146
8/17/93	1.5	4.49	14.8	11.6	0.96	11.1	136	153	0.64	5.7	229		0.01	1.29	2.8	136
10/29/93	1.09	2.83	14.0	11.1	0.47	9.48	129	146	0.2	2.62	218	0.008	0.02	1.24	2.7	128
1/11/94	2.47		16.6	13.1	0.39		152	172	0.17		256			1.43	3.1	156
1/11/94	1.93	1.51	16.6	13.1	0.3	3.5	152	172	0.74	1.19	256	0.001	0.01	1.43	3.1	156
4/27/94			9.8	7.7		0.08	90	102			154			0.91	2.0	84
4/27/94			9.8	7.7		0.24	90	102			154			0.91	2.0	84
4/27/94	1.17	3.58	9.8	7.7	0.48	9.24	90	102	0.4	4.4	154	0.002	0.01	0.91	2.0	84
4/27/94	0.68		9.8	7.7	0.54		90	102	0.34		154			0.91	2.0	84
3/11/95		34.1	12.7	10.0		107	117	132		69.1	198		0.17	1.14	2.5	114
3/22/95		2.89	9.8	7.7		5.87	90	102		2.11	154		0.02	0.91	2.0	84

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)

D—042719

Table 29. Summary of Metal Concentration Data 1993-1995

San Joaquin River at Vernalis

DATE	NICKEL				LEAD			HARDNESS
	D	T	O*	O#	D	T	O*#	
7/7/93	2.23	11.2	217	72		1.43	3.8	146
8/17/93	1.7	8.9	204	67		1.13	3.5	136
10/29/93	1.13	4.03	194	64	0.04	0.14	3.3	128
1/11/94	0.95		229	76			4.1	156
1/11/94	1.93	2	229	76	0.15	0.06	4.1	156
4/27/94			136	45			2.1	84
4/27/94			136	45			2.1	84
4/27/94	0.97	5.53	136	45	0.07	0.79	2.1	84
4/27/94	0.88		136	45	0.09		2.1	84
3/11/95		128	176	58		17.6	2.9	114
3/22/95		3.97	136	45		5.43	2.1	84

D-042720

Table 30. Summary of Metal Concentration Data 1995
Greene's Landing
Page 1 of 6

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
1/6/95	2.99	5.54	10.6	8.3	3.2	10.2	97	110	1.28	3.71	166	0.03	0.06	0.97	2.1	92
1/7/95	3.39	9.02	8.0	6.3	3.75	17.9	73	83	1.98	7.2	127	0.03	0.12	0.76	1.6	66
1/8/95	4.91	10.6	7.3	5.8	5.59	19.7	68	77	2.94	11.4	117	0.04	0.11	0.71	1.5	60
1/10/95	4.9	28.4	6.5	5.1	5.99	62.9	60	68	3	29	104	0.04	0.47	0.64	1.4	52
1/12/95	3.35	17.4	5.4	4.3	2.86	33.1	50	57	3.2	19.3	87	0.03	0.18	0.54	1.2	42
1/13/95	3.67	14.2	7.1	5.6	6.32	32.5	66	74	4.78	21	114	0.04	0.17	0.69	1.5	58
1/14/95	3.94	15.2	5.2	4.1	11.2	71.8	48	54	4.42	21.3	84	0.02	0.17	0.52	1.1	40
1/15/95	3.62	10.7	5.6	4.4	7.93	44.8	52	59	3.05	12.2	91	0.03	0.11	0.56	1.2	44
1/17/95	3.6	9.39	5.6	4.4	9.4	18.4	52	59	3.4	11.6	91	0	0.09	0.56	1.2	44
1/18/95	3.68	10.3			4.68	46.9			3.83	13.3		0.03	0.09			no data
1/20/95	4.28	9.68	6.1	4.8	4.84	19.5	56	63	3.43	12.6	98	0.11	0.09	0.60	1.3	48
1/22/95	3.35	9.98	6.7	5.3	4.25	23.3	62	70	2.5	12	107	0.03	0.1	0.65	1.4	54
1/23/95	3.42	9.43	6.3	5.0	4.41	25.4	58	66	2.52	8.57	101	0.02	0.09	0.62	1.3	50
1/24/95	3.09	8.27	6.9	5.5			64	72	2.68	8.44	111	0.03	0.08	0.67	1.5	56
1/25/95	2.88	7.07	6.7	5.3	5.06	20.9	62	70	4.43	8.27	107	0.03	0.08	0.65	1.4	54
1/26/95	3.16	9.9	6.3	5.0	4.86	24.4	58	66	2.07	11	101	0.03	0.11	0.62	1.3	50
1/27/95	3.27	8.82	6.1	4.8	6.06	22.3	56	63	4.46	10.6	98	0.03	0.08	0.60	1.3	48

D-042721

Table 30. Summary of Metal Concentration Data 1995
Greene's Landing

DATE	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
1/28/95	2.77	8.11	6.1	4.8	5.9	21.7	56	63	2.07	9.84	98	0.07	0.08	0.60	1.3	48
1/29/95	2.89	7.34	5.6	4.4	4.34	17.8	52	59	2.13	7.75	91	0.03	0.11	0.56	1.2	44
1/30/95	2.87	6.79	6.1	4.8	2.47	14.4	56	63	1.75	7.17	98	0.02	0.05	0.60	1.3	48
1/31/95	1.89	7.02	6.1	4.8	3.98	14.6	56	63	1.59	6.77	98	0.02	0.1	0.60	1.3	48
2/1/95		3.53	6.3	5.0		12.2	58	66		5.02	101		0.07	0.62	1.3	50
2/2/95		5.9	6.3	5.0		13.3	58	66		4.88	101		0.04	0.62	1.3	50
2/3/95		6.57	6.1	4.8		14.3	56	63		6.03	98		0.06	0.60	1.3	48
2/6/95	2.37	6.45	5.8	4.6	3.6	14.5	54	61	1.68	5.78	94	0.03	0.05	0.58	1.3	46
2/10/95	2.49	4.95			2.41	10.6			1.41	4.47		0.01	0.06			no data
2/14/95		5.07								4.65			0.06			no data
2/17/95		7.3								8.79			0.11			no data
2/21/95		4.99								4.16			0.05			no data
2/23/95		4.78								3.93			0.05			no data
2/24/95		4.08								3.9			0.06			no data
2/28/95		4.14								3.97			0.05			no data
3/3/95		4.75								4.44			0.07			no data
3/5/95		4.94								5.02			0.08			no data

D-042722

D — 0 4 2 7 2 2

Table 30. Summary of Metal Concentration Data 1995
Greene's Landing

	COPPER				ZINC				CHROMIUM (III)			CADMIUM				HARDNESS
DATE	D	T	O*	O#	D	T	O*	O#	D	T	O*#	D	T	O*	O#	
3/7/95		5.73								4.94			0.05			no data

* = USEPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
# = USEPA Proposed California Toxics Rule Criteria to Protect Freshwater Aquatic Life (expressed as dissolved metal 4-day average criteria)
† = California Proposition 65 Regulatory Level as Drinking Water Level

Table 30. Summary of Metal Concentration Data 1995
Green's Landing

DATE	NICKEL				LEAD			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	
1/6/95	2.19	6.02	146	48	0.45	1.2	2.3	1.41	1.52	5	92
1/7/95	2.97	10.5	111	37	0.78	3.48	1.6		1.2	5	66
1/8/95	4.51	16	102	34	0.77	3.91	1.4	0.45	0.3	5	60
1/10/95	4.31	3.16	90	30	0.81	11.2	1.2	1.37		5	52
1/12/95	8.5	27.1	75	25	0.53	3.69	1.0	1.19	1.32	5	42
1/13/95	4.78	23.6	99	33	0.65	4.02	1.4	1.14	1.09	5	58
1/14/95	6.02	26.9	72	24	0.8	2.66	0.9	0.84	2.45	5	40
1/15/95	19.1	13.8	78	26	0.48	2.55	1.0	0.91	0.9	5	44
1/17/95	26	24.8	78	26	0.49	1.57	1.0	1.12	0.72	5	44
1/18/95	6.21	23.7			0.52	7.42		1.06	0.61	5	no data
1/20/95	6.33	18	84	28	0.54	2.05	1.1	1.07	1.2	5	48
1/22/95	3.75	16.2	93	31	0.4	1.75	1.3	1.36	1.4	5	54
1/23/95	4.45	13.1	87	29	0.43	3.24	1.2	1.09	1.22	5	50
1/24/95	3.46	11.8	96	32	0.36	1.55	1.3	1.25	1.07	5	56
1/25/95	4.07	12	93	31	0.4	2.11	1.3	1.14	1.52	5	54
1/26/95	4.34	17.4	87	29	0.35	1.83	1.2	1.25	1.59	5	50
1/27/95	4.06	16.2	84	28	0.46	2.28	1.1	1.18	1.08	5	48

D-042724

Table 30. Summary of Metal Concentration Data 1995
Green's Landing

	NICKEL				LEAD			ARSENIC			HARDNESS
DATE	D	T	O*	O#	D	T	O*#	D	T	O†	
1/28/95	4.34	15.7	84	28	0.41	2.06	1.1	1	1.24	5	48
1/29/95	3.95	10.8	78	26	0.34	1.63	1.0	1.22	1.13	5	44
1/30/95	3.11	11.3	84	28	0.24	1.04	1.1		1.18	5	48
1/31/95	2.99	10.6	84	28	0.37	1.04	1.1		1.54	5	48
2/1/95		6.61	87	29		1.08	1.2				50
2/2/95		5.92	87	29		0.86	1.2				50
2/3/95		8.45	84	28		1.33	1.1				48
2/6/95	2.44	8.63	81	27	0.25	1.11	1.1				46
2/10/95	2.15	7.1			0.18	0.63					no data
2/14/95		6.71				0.65					no data
2/17/95		12.3				1.08					no data
2/21/95		7.04				4.48					no data
2/23/95		6.31				1.56					no data
2/24/95		4.59				6.94					no data
2/28/95		5.85				1.16					no data
3/3/95		5.79				2.86					no data
3/5/95		6.56				0.96					no data

D—042725

Table 30. Summary of Metal Concentration Data 1995
Green's Landing
Page 6 of 6

DATE	NICKEL				LEAD			ARSENIC			HARDNESS
	D	T	O*	O#	D	T	O*#	D	T	O†	
3/7/95		6.18				1					no data

D-042727

Table 31. Number of Dissolved Metal Analyses and Events When Water Quality Objectives Were Exceeded for Stations Monitored from 1993 to 1995

STATION	NUMBER OF ANALYSES FOR DISSOLVED METALS	NUMBER OF EVENTS WHEN WATER QUALITY OBJECTIVE WERE EXCEEDED
Sacramento River @ Antioch	31	0
Duck Slough	34	0
French Camp Slough	14	0
Sacramento River @ Hood	57	0
Middle River @ Bullfrog Landing	28	0
Mokelumne River	25	0
Old River @ Tracy Blvd.	14	0
Paradise Cut	42	0
Prospect Slough	42	0
Sacramento River @ Rio Vista	61	0
Skag Slough	0	N/A
San Joaquin River @ Stockton	16	0
Ulatis Creek	7	0
San Joaquin River @ Vernalis	35	0
Greene's Landing	143	0
ALL STATIONS COMBINED	**549**	**0**

D-042727

Table 32. Summary of 1993-1994 Toxicity Monitoring Data

Waterway Category	Ceriodaphnia		Selenastrum		Pimephales	
	# Events Testing Toxic (sample size)	Toxicity Related to:	# Events Testing Toxic (sample size)	Toxicity Related to:	# Events Testing Toxic (sample size)	Toxicity Related to:
Main River Inputs into the Delta	2 (29)	diazinon (2) and unknown (1)	0 (26)	N/A	5 (25)	*
Island Drains	1 (49)	no TIE	0 (45)	N/A	2 (41)	*
Back-sloughs and Small Upland Drainages	10 (73)	chlorpyrifos (2)†, carbofuran (2)†, and unknown (9)	1 (65)	non-polar organic(1)	7 (62)	*
Urban Runoff Receiving Water	0 (10)	N/A	0 (9)	N/A	0 (8)	N/A
Points Along the Pathways of Water Movement Across the Delta	3 (76)	no TIE	0 (68)	N/A	3 (63)	*
Total Frequency	16 (237)		1 (213)		17 (199)	

† = linked to toxicity in fixed-date samples and follow-up samples

* = no TIEs conducted due to the chronic nature of the observed toxicity

D-042728

D-042729

Table 33. Summary of Toxicity Monitoring Data 1994-1995

Waterway Category	Ceriodaphnia		Selenastrum		Pimephales	
	# Events Testing Toxic (sample size)	Toxicity Related to (# events):	# Events Testing Toxic (sample size)	Toxicity* Related to (# events):	# Events Testing Toxic (sample size)	Toxicity Related to:
Main River Inputs into the Delta	2 (28)	unknown	6 (20)	unknown	(0) 14	N/A
Island Drains	1 (32)	carbaryl (1)	3 (8)	non-polar organic (1) and unknown (2)	(0) 1	N/A
Back-sloughs and Small Upland Drainages	17 (104)	chlorpyrifos (14)†, diazinon (3), metabolically activated pesticides (2), and unknown (8)	20 (72)	non-polar organic (2) and unknown	(0) 2	N/A
Urban Runoff Receiving Water	4 (7)	diazinon (5)† and chlorpyrifos (4)	1 (5)	no TIE(^)	N/A	N/A
Points Along the Pathways of Water Movement Across the Delta	0 (1)	N/A	4 (11)	unknown	N/A	N/A
Total Frequency	24 (172)		29 (116)		(0) 17	

(^) = Storm water studies indicate toxicity to algae at Mosher Slough is partially caused by diuron and unknown chemicals

* : "toxicity" identified as sites sampled > four times and having reduced cell counts relative to other ambient station results

† = linked to toxicity in fixed-date samples and follow-up samples

D-042729

Table 34. Summary of Dissolved Metal Analyses from Samples Collected from 1993 through 1995 and Relationship to Documented Effects in the Literature

				Documented Effects in the Literature* at Highest Metal Concentrations Measured in this Study		
Metal	**Average Conc. (ppb)**	**Range (ppb)**	**Location of Highest Concentration**	**Fish**	**Invertebrates**	**Algae**
Copper	2.64	0.2-9.48	Greene's Landing	No	Yes*	Yes*
Zinc	4.39	0.16-70.2	5-mile	No	No	Yes*
Chromium	1.34	0.06-5.39	Duck Slough			
Lead	0.31	0.01-3.87	5-mile	Yes#	Yes#	No
Cadmium	0.03	0.001-0.55	Greene's Landing	Yes*	Yes*	No
Nickel	2.72	0.13-26	Greene's Landing			
Arsenic	1.28	0.13-3.03	5-mile	No	Yes#	Yes#

* = See Reyes, E. (1994) and **Appendix X** for species and effects.
# = See Tables 35-40.

D-042730

D-042730

Table 35. Summary of lead concentrations reported to have adverse effects on sensitive freshwater algal and diatom species

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (µg/L) *	Hardness (mg/L as CaCO3)	Reference	Where cited
Chlorella pyrenoidosa, green algae	lead	4 d	change in cell number	10.35		J. L. Stauber & T. M. Florence, 1987. Ref. No. 12971	2
Anabaena sp., blue green algae	lead nitrate	20 d	change in cell number	21		V. M. Laube et al., 1980. Ref. No. 9477	2
Scenedesmus quadricauda, green algae	lead acetate	14 d	change in chlorophyll content	80		M. Pawlaczyk-Szpilowa et al., 1972. Ref. No. 2741	2
Haematococcus capensis, green algae	lead acetate	7 d	change in cell number	100		T. C. Hutchinson, 1973. Ref. No. 8864	2
Phytoplankton, mixed species	lead acetate	4 d	change in biomass	100		K. Pietilainen, 1975. Ref. No. 8184	2
Chlamydomonas reinhardtii, green algae	lead chloride	1 d	change in chlorophyll content	207		U. Irmer, et al., 1986. Ref. No. 12272	2
Phytoplankton, mixed species	lead chloride	5 d	change in cell number	207		J. T. Hollibaugh et al., 1980. Ref. No. 5282	2
Scenedesmus acuminatus, green algae	lead	6 d	EC50 for change in population size	250		P. M. Stokes, 1981. Ref. No. 9501	2
Selenastrum capricornutum, green algae	lead	1 d	EC50 for change in cell number	285	4.4	C. Y. Chen & K. C. Lin, 1997. Ref. No. 18103	2
Anacystis aeruginosa, blue-green algae	lead acetate	8 d	change in cell number	450		G. Bringmann & R. Kuhn, 1978. Ref. No. 15143	2
Chlorella sp., green algae	lead chloride		53% growth inhibition	500		T. J. Monahan, 1976	1
Scenedesmus obtusiusculus, green algae	lead chloride	7 d	35% growth inhibition	500		T. J. Monahan, 1976	1, 2
Selenastrum sp., green algae	lead chloride		52% growth inhibition	500		T. J. Monahan, 1976	1
Micrasterias thomasiana, green algae	lead chloride	2 hr	histological alteration	849		U. Meindl & G. Roderer, 1990. Ref. No. 3151	2
Chlorella vulgaris, green algae	lead chloride	33 d	change in cellular structure	1000		J. J. Rosko & J. W. Rachlin, 1977. Ref. No. 2259	2
Scenedesmus quadricauda, green algae	lead chloride	15 d	change in cell number	1000		M. E. Starodub et al., 1987. Ref. No. 12817	2

1 - Cited in Lead Criteria Document 1984 (USEPA, 1985); 2 - Cited in AQUIRE Database

* Concentration is amount of lead in solution (eg., not as lead acetate); EC50 - median effective concentration

D-042731

D-042732

Table 36. Summary of lead concentrations reported to have adverse effects on sensitive freshwater invertebrate species

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (µg/L)	Hardness (mg/L as CaCO3)	Reference	Where cited
Tetrahymena pyriformis, ciliate	lead chloride	4 min	change in oxygen uptake	0.75		J. L. Slabbert & W. S. G. Morgan, 1982. Ref. No. 11048	1
Asellus aquaticus, aquatic sowbug	lead nitrate	16 d	LT50	10		L. Migliore & M. De Nicola Giudici, 1990. Ref. No. 10515	1
Lymnaea palustris, marsh snail (freshwater)	lead nitrate	133 d	mortality	12		U. Borgmann et al., 1978. Ref. No. 8314	1
Hyalella azteca, amphipod	lead	8 d	LC50	less than 16		G. L. Phipps et al., 1995. Ref. No. 14907	1
Daphnia magna, water flea	lead acetate	1.7 d	change in biochemical processes	16		R. Berglind et al., 1985. Ref. No. 10906	1
Aeshna cyanea, blue-green dragonfly larvae	lead nitrate	42 d	enzyme alterations	20		W. Meyer et al., 1986. Ref. No. 12306	1
Astacus astacus, European crayfish	lead	14 d	changes in enzymes, histological damage	20	70	W. Meyer et al., 1991. Ref. No. 376	1
Libuella depressa, dragonfly	lead nitrate	42 d	enzyme alterations	20		W. Meyer et al., 1986. Ref. No. 12306	1
Neanthes arenaceodentata, polychaete	lead chloride	183 d	LOEC for reproductive alterations	20		D. J. Reish & T. V. Gerlinger, 1984. Ref. No. 4007	1
Tubifex tubifex, tubificid worm	lead nitrate	4 d	EC50 for immobilization	42		B. S. Khangarot, 1991. Ref. No. 2918	1
Anopheles stephensi, mosquito	lead acetate	1 d	genetic alteration	60		G. P. Sharma et al., 1988. Ref. No. 5315	1
Caenorhabditis elegans, nematode	lead nitrate	4 d	LC50	60		P. L. Williams & D. B. Dusenbery, 1990. Ref. No. 3437	1
Daphnia similis, water flea	lead acetate	4 d	LC50	60		S. Soundrapandian & K. Venkataraman, 1990. Ref. No. 3945	1
Dreissena polymorpha, zebra mussel	lead nitrate	70 d	change in filtration rate	91		M. H. S. Draak et al., 1994. Ref. No. 14043	1
Biomphalaria glabrata, freshwater snail	lead nitrate	28 d	LT50	100		O. Ravera, 1977. Ref. No. 15474	1
Dugesia dorotocephala, planarian (flatworm)	lead	10 hr.	change in behavior	100		M. M. Kapu & D. J. Schaeffer, 1991. Ref. No. 10581	1
Gammarus pseudolimnaeus, amphipod	lead nitrate	4 d	EC50 for immobilization	124		R. L. Spehar et al., 1978. Ref. No. 2104	1
Cristigera sp. ciliate	lead nitrate	4 hr	change in population	150		J. S. Gray, 1974. Ref. No. 8558	1

1 - Cited in AQUIRE references; LC50 - medain lethal concentration; LT50 - median survival time; LOEC - Lowest observable effect concentration

D-042732

Table 37. Summary of lead concentrations reported to have adverse effects on sensitive freshwater fish species

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (µg/L)	Hardness (mg/L as CaCO3)	Reference	Where cited
Gasterosteus aculeatus, three-spine stickleback	lead nitrate	4.75	LT50	0.2		J. R. E. Jones, 1938. Ref. No. 2657	2
Phoxinus phoxinus, minnow	lead nitrate	21 d	mortality	0.5		J. R. E. Jones, 1938. Ref. No. 2657	2
Carassius auratus, goldfish	lead nitrate	4.75 d	physiological change	8		J. R. E. Jones, 1938. Ref. No. 2657	2
Pimephales promelas, fathead minnow	lead nitrate	2.94 d	LT50	10		E. K. Biegert & V. Valkovic. Ref. No. 5302	2
Salmo gairdneri, rainbow trout	lead nitrate	4 d	LT50	10		E. K. Biegert & V. Valkovic. Ref. No. 5302	2
Barbus conchonius, rosy barb	lead nitrate	30 d	change in biochemical process	47.4		H. Tewari et al., 1987. Ref. No. 12599	2
Salvelinus namaycush, lake trout	lead nitrate	115 d	mortality	48		S. Sauter, et al., 1976. Ref. No. 8439	2
Salvelinus fontinalis, brook trout	lead nitrate	40 d	change in blood parameters	58		G. Christensen et al., 1977. Ref. No. 7027	2
Salmo salar, Atlantic salmon	lead nitrate	30 d	LC50	60		M. Grande & S. Andersen, 1983. Ref. No. 10982	2
Brachydanio rerio, zebrafish	lead	1 d	physiological change	72		P. T. E. Ozoh, 1980. Ref. No. 9870	2
Ictalurus punctatus, channel catfish	lead nitrate	68 d	mortality	75		S. Sauter, et al., 1976. Ref. No. 8439	2
Catostomus commersoni, white sucker	lead nitrate	73 d	change in growth	119		S. Sauter, et al., 1976. Ref. No. 8439	2
Cyprinus carpio, common carp	lead nitrate	4 d	LC50	170		T. S. Rao, et al., 1975. Ref. No. 2077	2
Micropterus salmoides, largemouth bass	lead chloride	8 d	LC50	240		W. J. Birge, et al., 1978. Ref. No. 6199	2
Esox lucius, northern pike	lead nitrate	24 d	mortality	253		S. Sauter, et al., 1976. Ref. No. 8439	2

1 - Cited in Lead Criteria Document 1984 (USEPA, 1985); 2 - Cited in AQUIRE Database

* Concentration is amount of lead in solution (eg., not as lead acetate); LC50 - median lethal concentration; LT50 - median time for 50% survival

D-042734

Table. 38 Summary of arsenic concentrations reported to have adverse effects on sensitive species of freshwater algae

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (μg/L)	Reference	Where cited
Phytoplankton, freshwater species	arsenic acid, sodium salt	109 d	EC50 for change in photosynthetic productivity	1.5	S. A. Wangberg et al., 1991. Ref. No. 9419	2
Scenedesmus obliquus, green algae	arsenic acid, disodium salt	1 hr	change in photosynthetic productivity	48	O. Hofslagare et al., 1994. Ref. No. 16290	2
Clorella vulgaris, green algae	arsenic acid, disodium salt	91 d	LOEC for population growth	60	L. E. Den Dooren de Jong, 1965. Ref. No. 2849	2
Chlamydomonas sp., green algae	arsenic acid, disodium salt	28 d	change in population growth	75	E. R. Christensen & P. A. Zielski, Ref. No. 9773	2
Melosira granulata, diatom	arsenic acid, trisodium salt	20 d	change in population growth	75	D. Planas & F. P. Healey, 1978. Ref. No. 7146	1, 2
Ankistrodesmus falcatus, green algae	arsenic acid, disodium salt	14 d	EC50 for growth	256	Vocke et al., 1980. Ref. No. 5342	1, 2
Selenastrum capricornutum, green algae	arsenic acid, trisodium salt	4 d	EC50 for population growth	690	Richter, 1982	1

1 - Cited in Lead Criteria Document 1984 (USEPA, 1985); 2 - Cited in AQUIRE Database

* Concentration is amount of arsenic in solution (eg., not as arsenic acid salt)

EC50 - median effective concentration; LOEC - lowest observable effect concentration

D-042734

D-042735

Table 39. Summary of arsenic concentrations reported to have adverse effects on sensitive species of freshwater invertebrates

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (µg/L)	Reference	Where cited
Daphnia pulex, water flea	arsenic oxide	1 d	EC50 for immobilization	0.5	H. Lilius et al., 1995. Ref. No. 16385	2
Bosmina longirostris, water flea	arsenic acid, sodium salt	4 d	EC50 for immobilization	10	A. Novak et al., 1980. Ref. No. 2210	2
Tetrahymena pyriformis, ciliate	arsenic oxide	4.3 min.	change in oxygen uptake	25	J. L. Slabbert & J. P. Maree, 1986. Ref. No. 12836	2
Moina macropa, water flea	arsenic acid, disodium salt	7 d	mortality, changes in growth, reproduction	100	S. Maeda et al., 1990. Ref. No. 3118	2
Helisoma campanulatum, ramshorn snail	arsenic oxide	28 d	mortality	961	R. L. Spehar et al., 1980. Ref. No. 9783	2
Daphnia magna, water flea	arsenic pentoxide	14 d	mortality, altered reproduction	961	R. L. Spehar et al., 1980. Ref. No. 9784	2
Ceriodaphnia dubia, water flea	arsenic acid, sodium salt	8 d	altered reproduction	1020	R. B. Naddy et al., 1995. Ref. No. 13729	2

1 - Cited in Lead Criteria Document 1984 (USEPA, 1985); 2 - Cited in AQUIRE Database

EC50 - median effective concentration

* Concentration is amount of arsenic in solution (eg., not as arsenic acid salt)

Table 40. Summary of arsenic concentrations reported to have adverse effects on sensitive freshwater fishes

Species name	Chemical	Duration or test type	Effect/Endpoint	Concentration (µg/L)	Hardness (mg/L as CaCO3)	Reference	Where cited
Oncorhynchus mykiss, rainbow trout	arsenic acid	1 d	physiological change	25		A. A. Oladimeji, 1984. Ref. No. 10888	2
Carassius aratus, goldfish	arsenic acid, monosodium salt	2 d	behavioral change	100		P. A. Weir & C. H. Hine, 1970. Ref. No. 908	2
Lepomis cyanellus, green sunfish	arsenic acid, disodium salt	2 d	LC50	150		E. M. B. Sorensen, 1976. Ref. No. 5549	2
Oncorhynchus kisutch, coho salmon parr	arsenic oxide	183 d	mortality, changes in growth and physiology	300		J. W. Nichols et al., 1984. Ref. No. 10236	2
Channa punctatus, snake-head catfish	arsenic acid, disodium salt	28 d	physiological change	1000		K. Ghosh & S. Jana, 1988. Ref. No. 814	2
Anabas testudineus, climbing perch	arsenic acid, disodium salt	12 hr	mortality	488		S. Jana & S. S. Sahana, 1989. Ref. No. 2618	2
Clarias batrachus, walking catfish	arsenic acid, disodium salt	13 hr	mortality	488		S. Jana & S. S. Sahana, 1989. Ref. No. 2619	2
Pimephales promelas, fathead minnow	arsenic pentoxide	30 d	change in growth	530		D. L. DeFoe, 1982. Ref. No. 3687	2
Oncorhynchus mykiss, rainbow trout	arsenic acid, disodium salt	77 d	mortality	1400		S. M. McGreachy & D. G. Dixon, 1990. Ref. No. 273	2

1 - Cited in Lead Criteria Document 1984 (USEPA, 1985); 2 - Cited in AQUIRE Database

LC50 - median lethal concentration

* Concentration is amount of arsenic in solution (eg., not as arsenic acid salt)

D—042736

Table 41. Comparison of Metal Load Estimates in the Sacramento River at Greene's Landing from January Through April During a Dry Year (1994) and Wet Year (1995)

Year and Method	Copper Total	Copper Daily Avg.	Zinc Total	Zinc Daily Avg.	Chromium Total	Chromium Daily Avg.	Lead Total	Lead Daily Avg.	Cadmium Total	Cadmium Daily Avg.	Nickel Total	Nickel Daily Avg.	Arsenic Total	Arsenic Daily Avg.
1994														
Average Concentration Method	22047	184	61790	515	16792	140	3612	30	398	3	22827	190		
Model	16660	142†	40985	350†	11796	101†	2688	23†	*	*	15855	136†		
1995														
Average Concentration Method	148818	1404^	380941	3594^	164282	1550^	56201	530^	1696	16^	209509	1977^	22281	210^
Model	*	*	*	*	*	*	*	*	*	*	*	*	*	*
% Increase	**893 (1)**		**929 (1)**		**1392 (1)**		**2091 (1)**		**426 (2)**		**1321 (1)**		**N/A**	

(1) = % increase from 1994 model calculation to 1995 average concentration method
(2) = % increase from 1994 average concentration method to 1995 average concentration method
* = Model could not be applied due to insignificant relationship between total metal concentrations and flow
† = Daily average based on 117 days when flows were recorded
^ = Daily average based on 106 days when flows were recorded

D-042738

Table 42. Comparison of Metal Load Estimates in the Sacramento River at River Mile 44 from January Through April of a Dry Year (1994) and Wet Year (1995) Based on Metal Analyses Conducted for the Sacramento Coordinated Water Quality Monitoring Program's Ambient Monitoring Program

Year and Method	Copper		Zinc		Chromium		Lead		Cadmium		Nickel		Arsenic	
	Total	Daily Avg.	Total	Daily Avg.	Total	Daily Avg.	Total	Daily Avg.	Total	Daily Avg.	Total	Daily Avg.	Total	Daily Avg.
1994														
Average Concentration Method	12029	100†	28863	241†	55837	47†	1642	14†	123	1†	9443	79†	7801	65†
% difference from BPTCP load estimates	(-55)		(-47)		(-33)		(-46)		(-31)		(-41)			
1995														
Average Concentration Method	95111	897^	196706	1856^	46724	441^	19288	182^	998	9^	102427	966^	21284	201^
% difference from BPTCP load estimates	(-64)		(-52)		(-28)		(-34)		(-59)		(-49)		(-96)	
% Increase in load from dry year to wet year	**791**		**682**		**84**		**1174**		**810**		**1085**		**273**	

† = Daily average based on 120 days when flows were recorded
^ = Daily average based on 106 days when flows were recorded

D—042738

D-042739

Table 43. Comparison of Metal Loads to the Delta Contributed by Sources Which Drain Into the Yolo Bypass and Sacramento River During High Flows From January Through April 1995

METAL	CONTRIBUTION	BYPASS	RIVER	TOTAL
Copper	Total	296189	148818	445007
	Daily Average	2848*	1404†	4258
	Percent	67	33	100
Zinc	Total	726726	380941	1107667
	Daily Average	6988*	3594†	10582
	Percent	66	34	100
Chromium	Total	472132	164282	636414
	Daily Average	4540*	1550†	6090
	Percent	74	26	100
Lead	Total	64664	56201	120865
	Daily Average	622*	530†	1152
	Percent	54	46	100
Cadmium	Total	1554	1696	3250
	Daily Average	15*	16†	31
	Percent	48	52	100
Nickel	Total	910798	209509	1120307
	Daily Average	8758*	1977†	10735
	Percent	81	19	100
Arsenic	Total	22352	22281	44633
	Daily Average	215*	210†	425
	Percent	50	50	100

* = Yolo Bypass daily average based on 104 days when USGS gage station #11453000 was functional
† = Sacramento River daily average based on 106 days when flows were recorded

D-042739

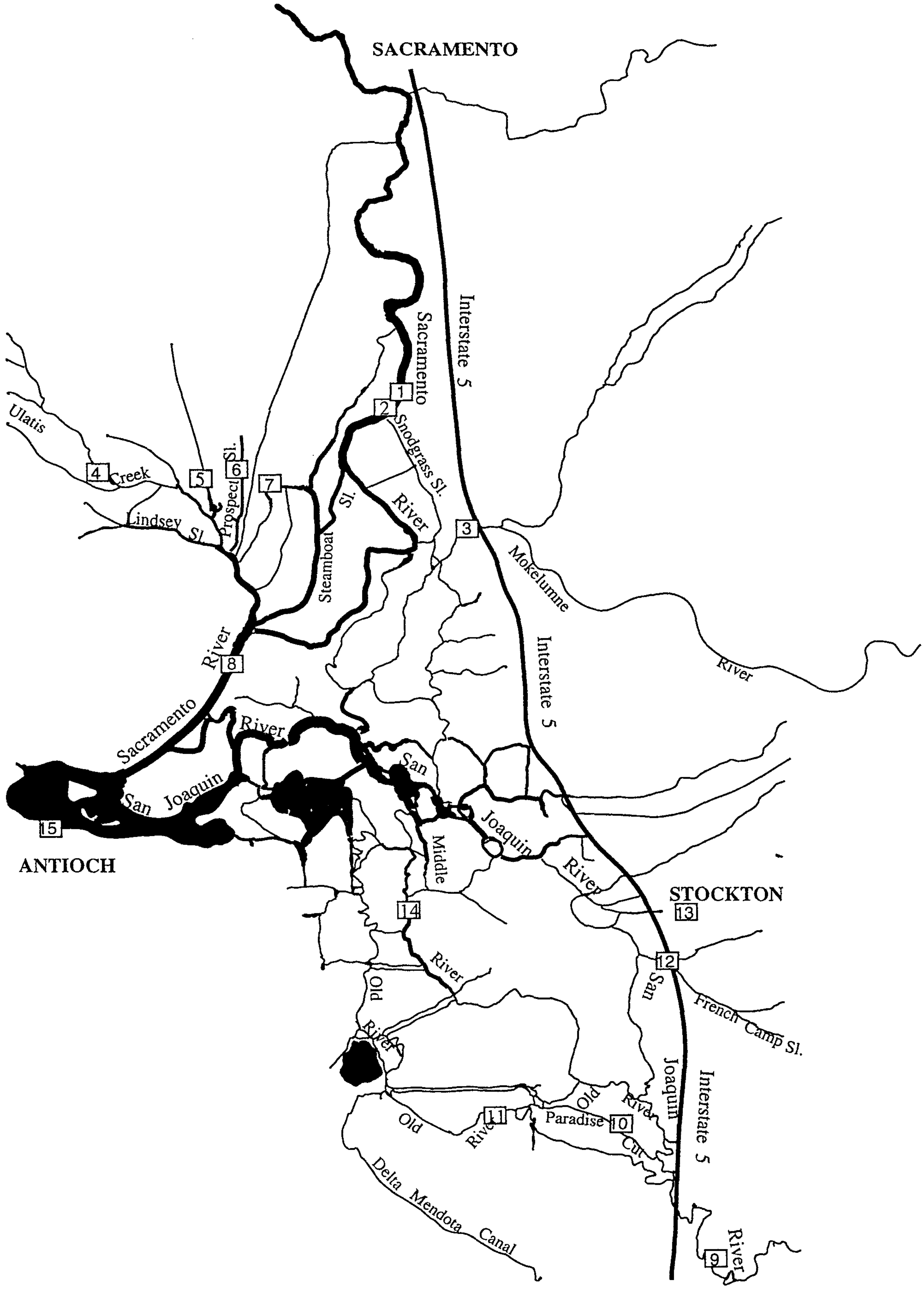


Figure 1. Map of the Sacramento-San Joaquin River Delta and its major tributaries. Numbers refer to sample stations described in Appendix A.

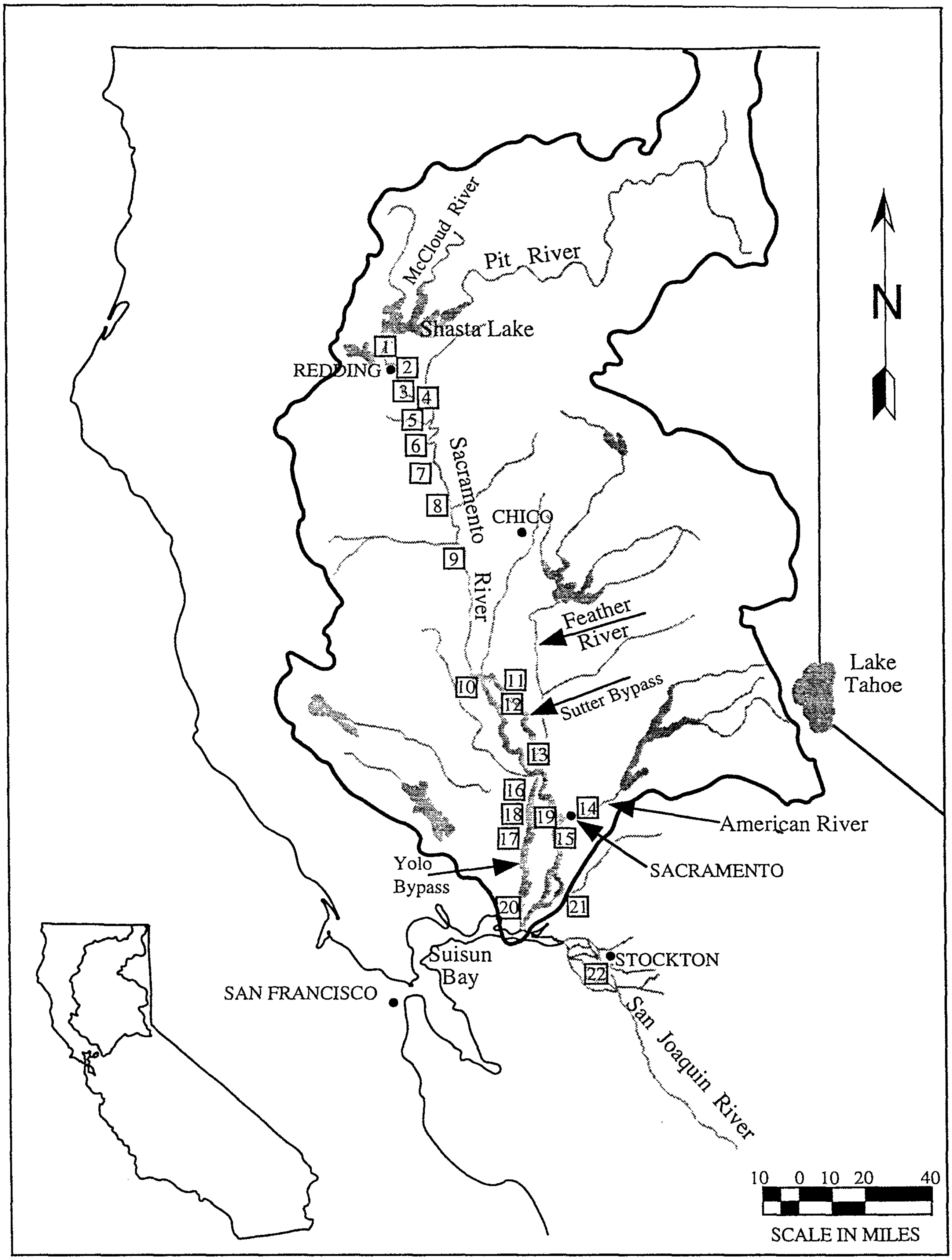


Figure 2. Map of the Sacramento River Watershed and its major tributaries. Numbers refer to sample stations described in Appendix A.

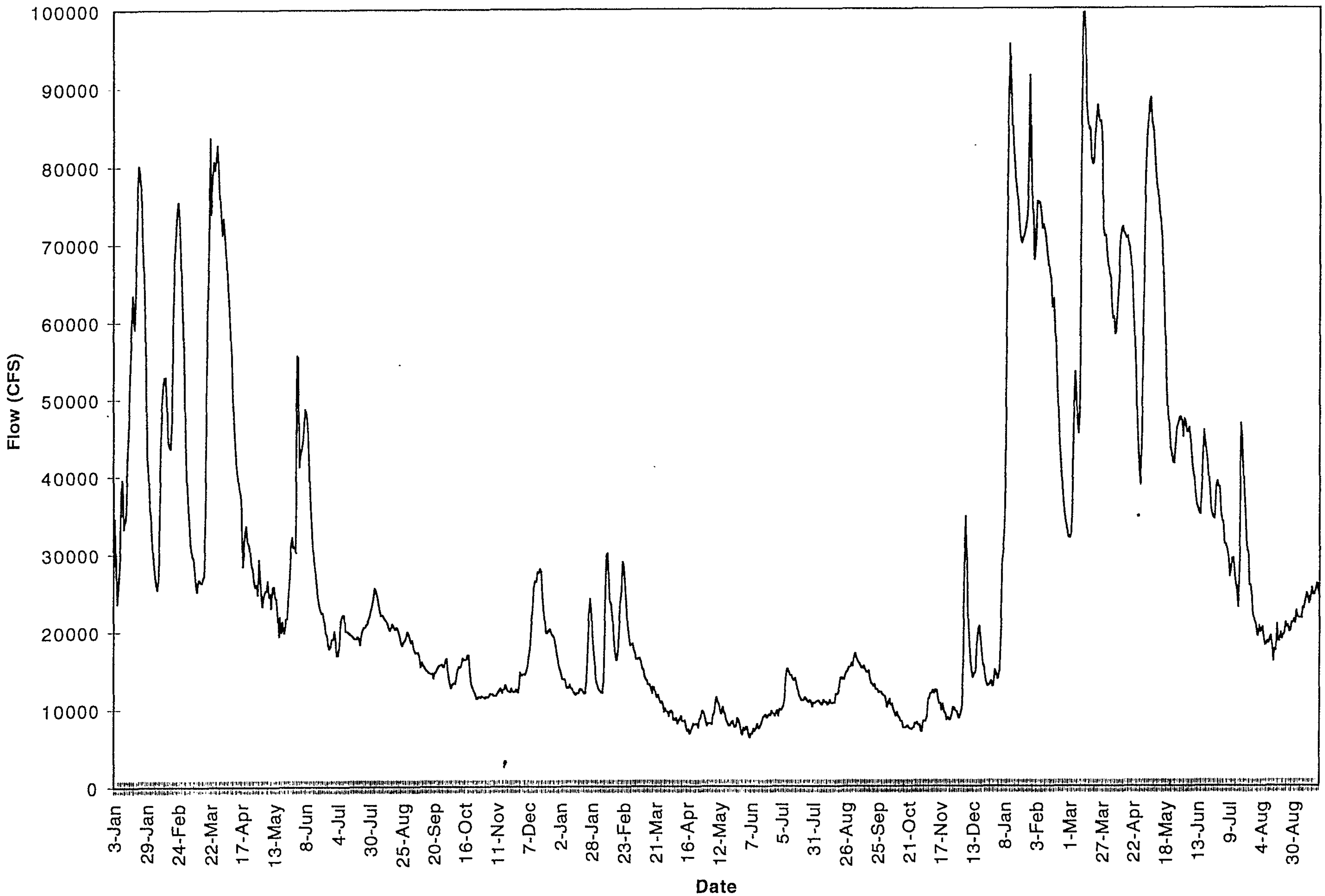


Figure 3. Sacramento River Flow at Freeport from January 1993 to September 1995

D—042742

BP TCP / Amt 12 dg

D-042743

BPTCP 1993-1994/Flow

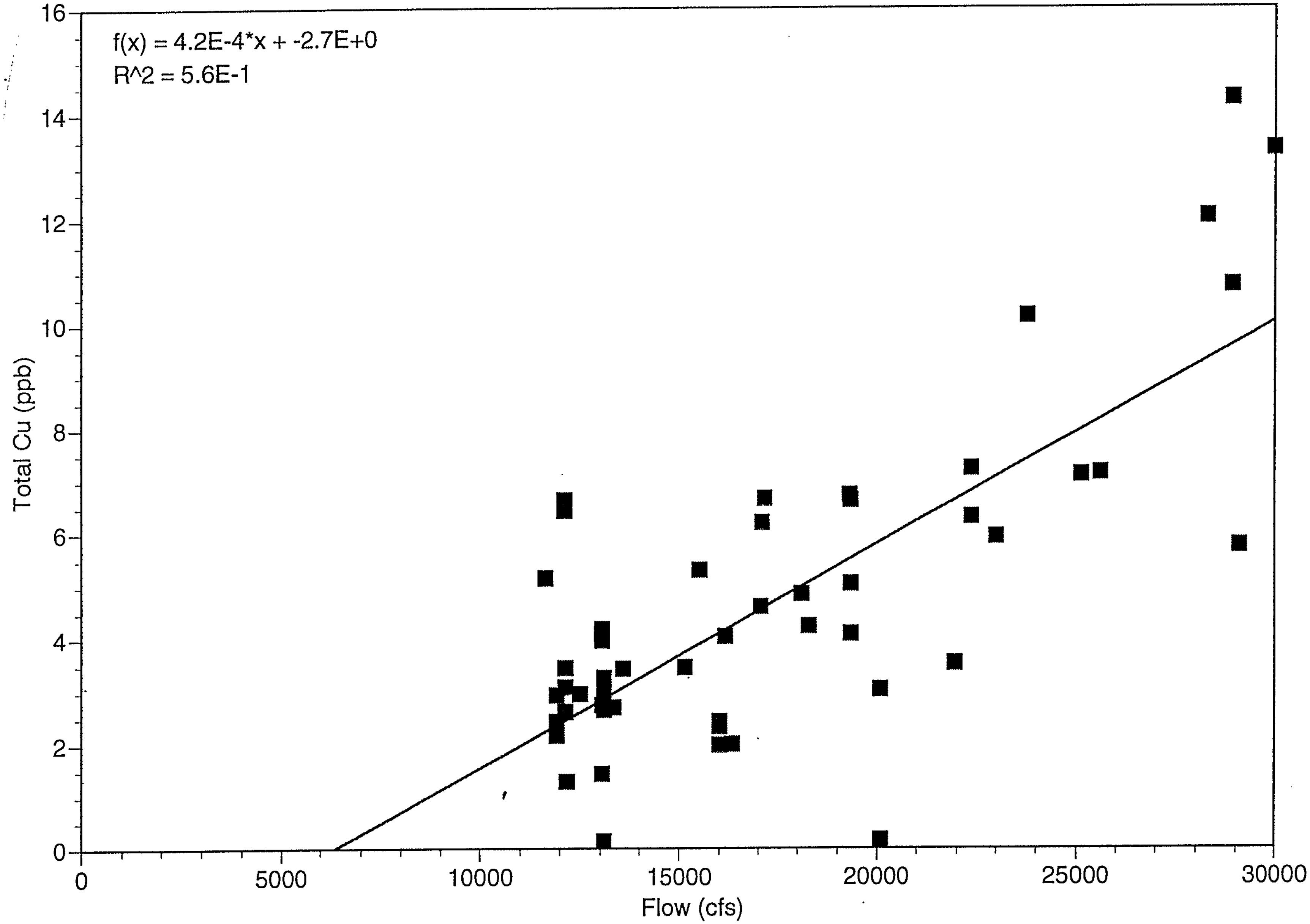


Fig 4

D-042743

BPTCP 1993-1994/Flow

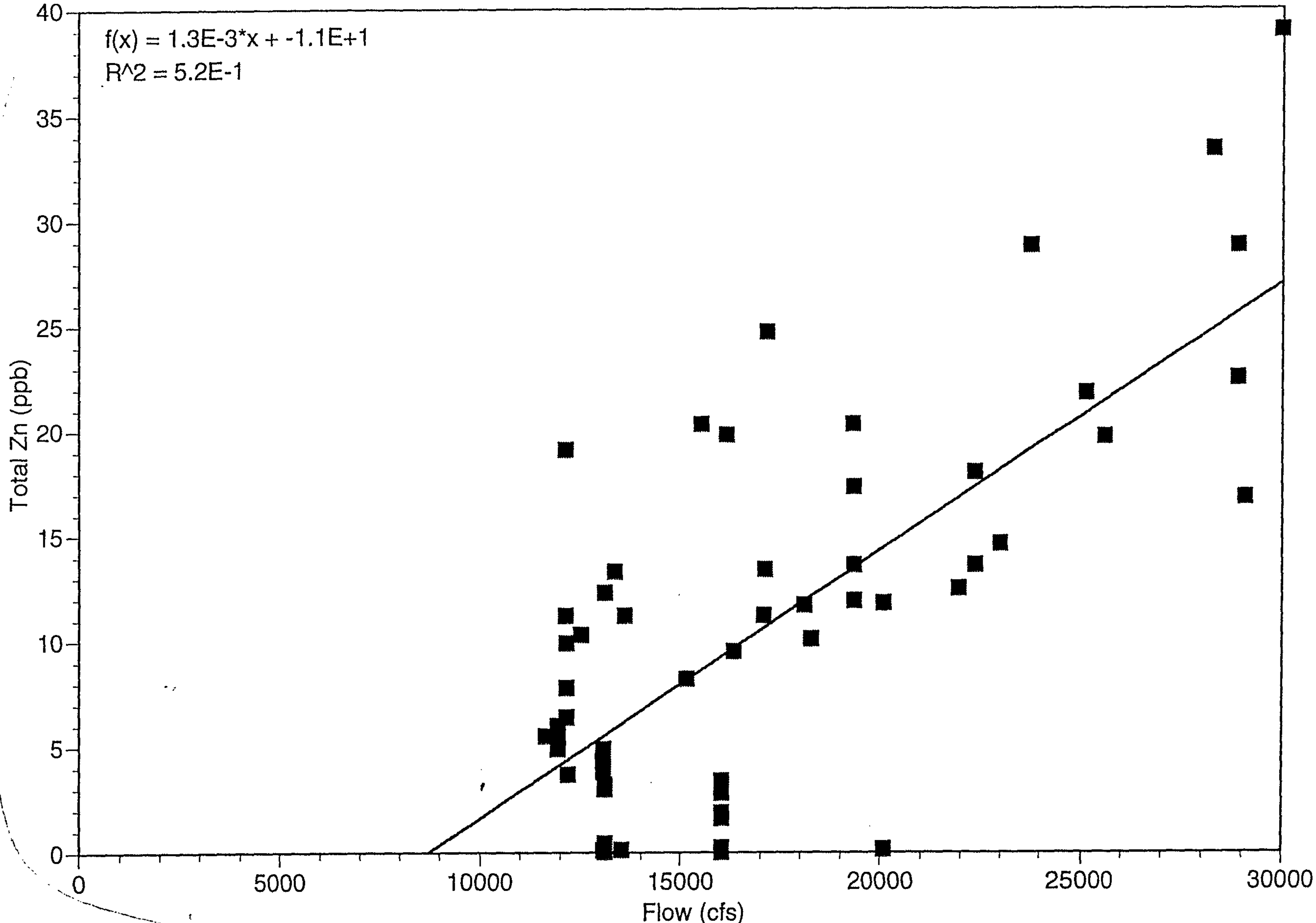


Fig 5

D-042744

D — 0 4 2 7 4 4

BPTCP 1993-1994/Flow

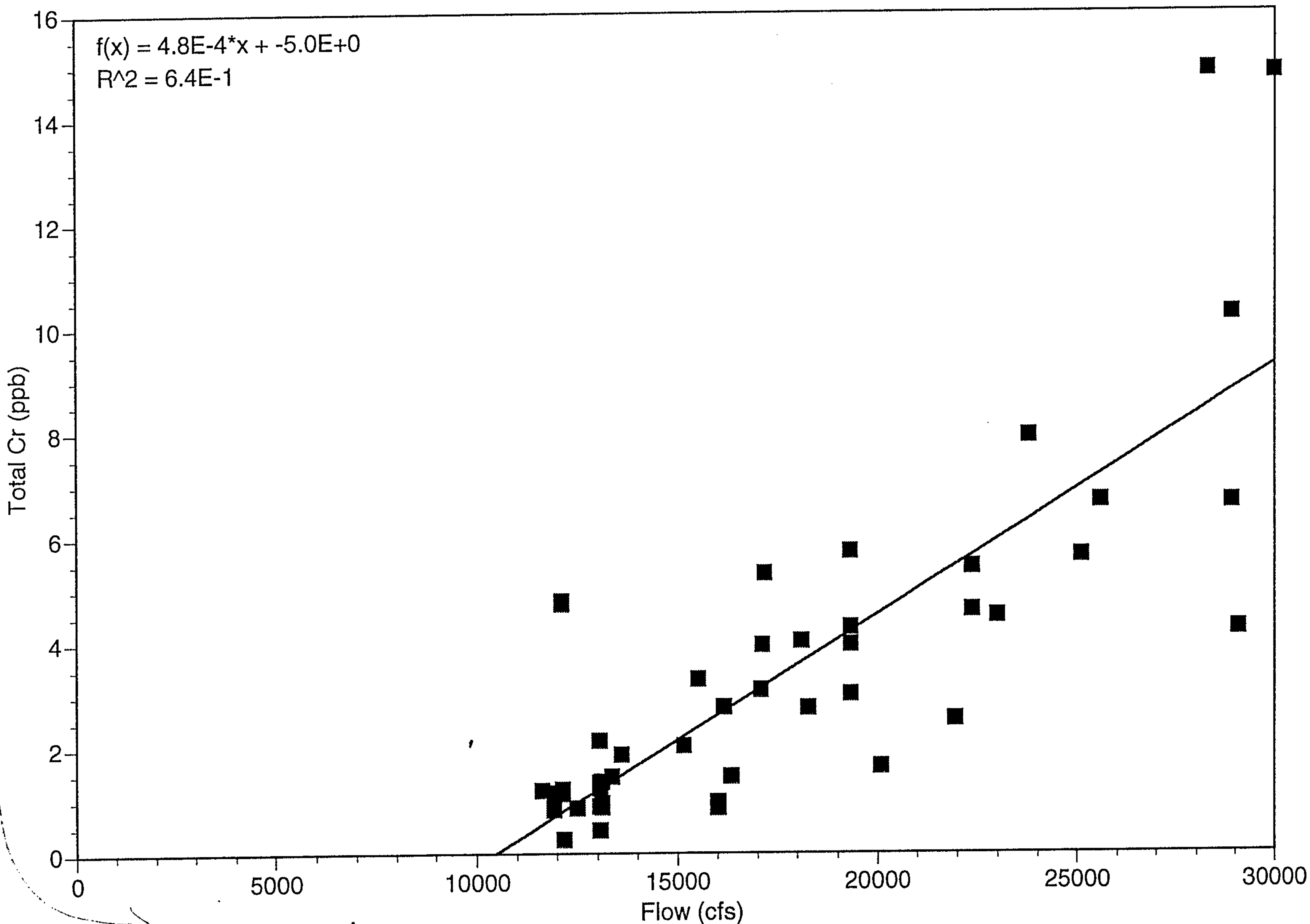
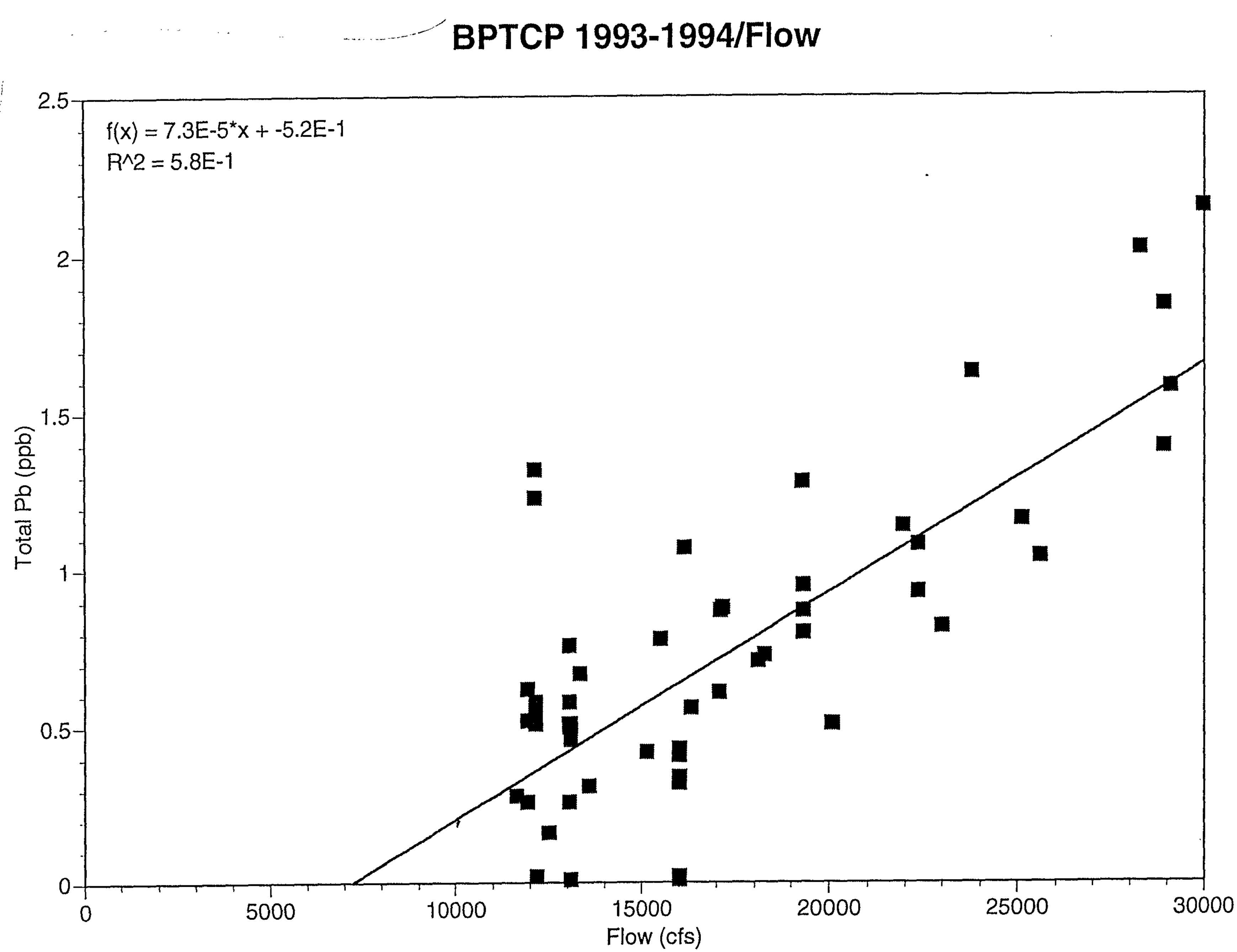


Fig 6

D-042745

D-042745



-> Fig 7

D-042746

BPTCP 1993-1994/Flow

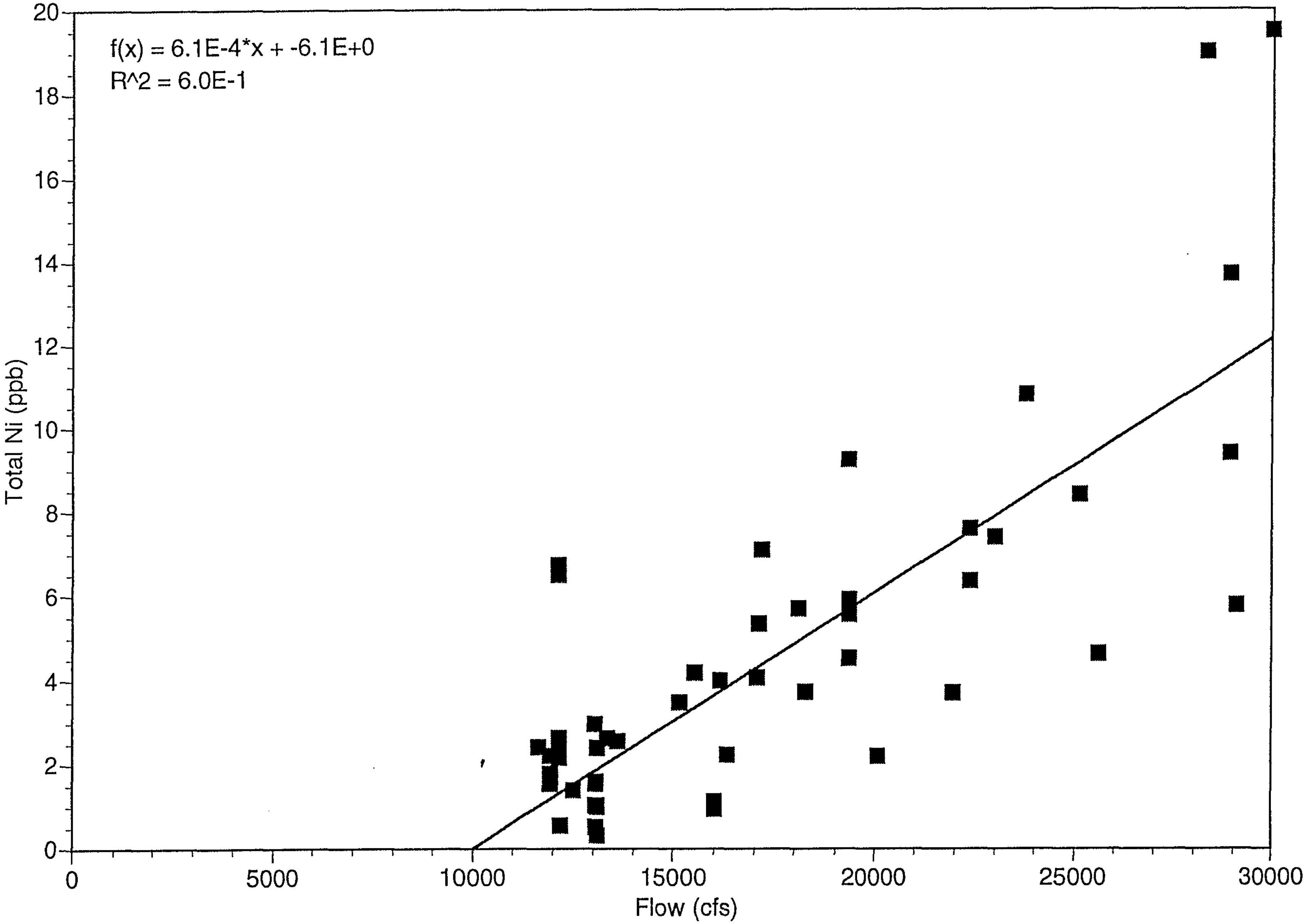


Fig 8.

BPTCP 1993-1994/[redacted] TSS

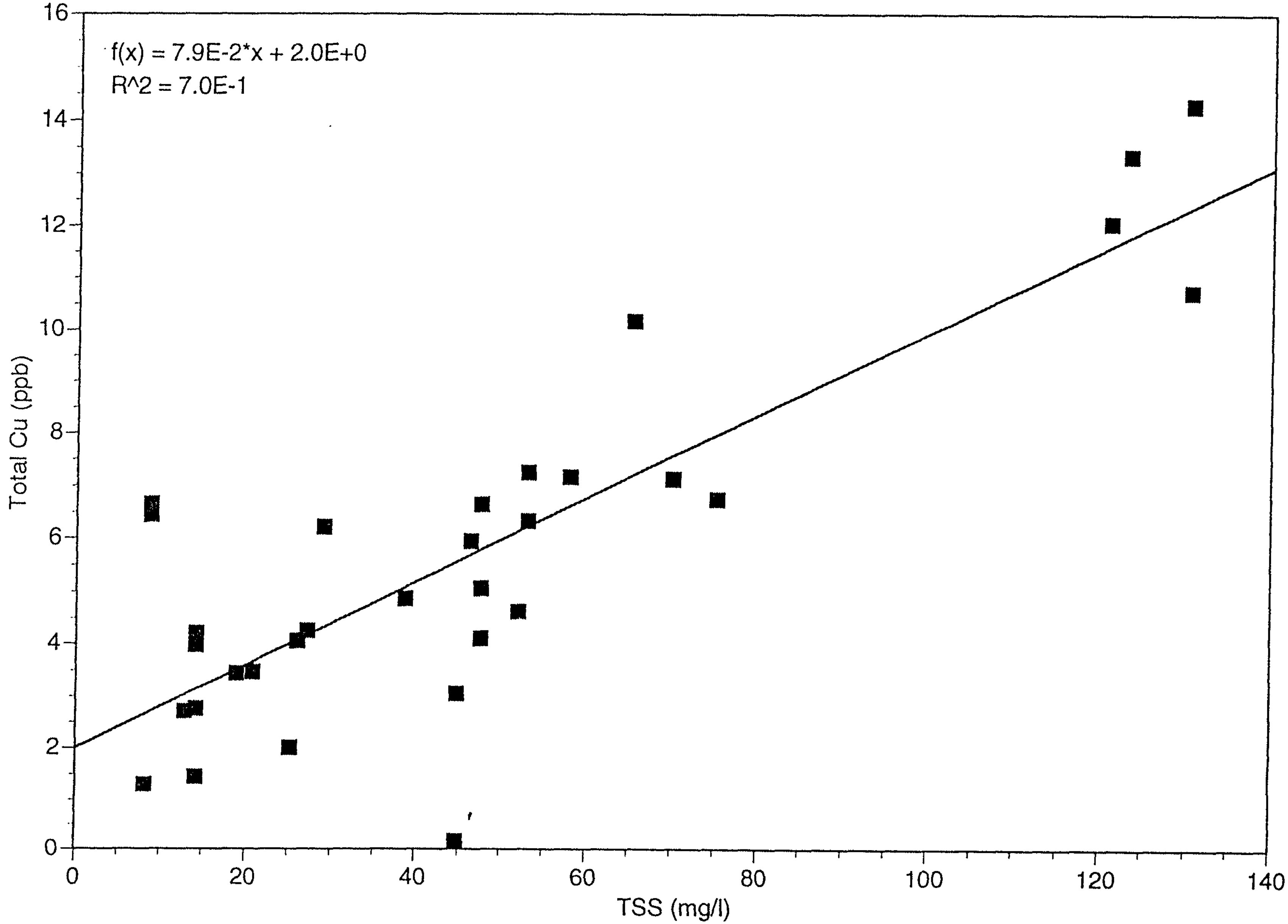
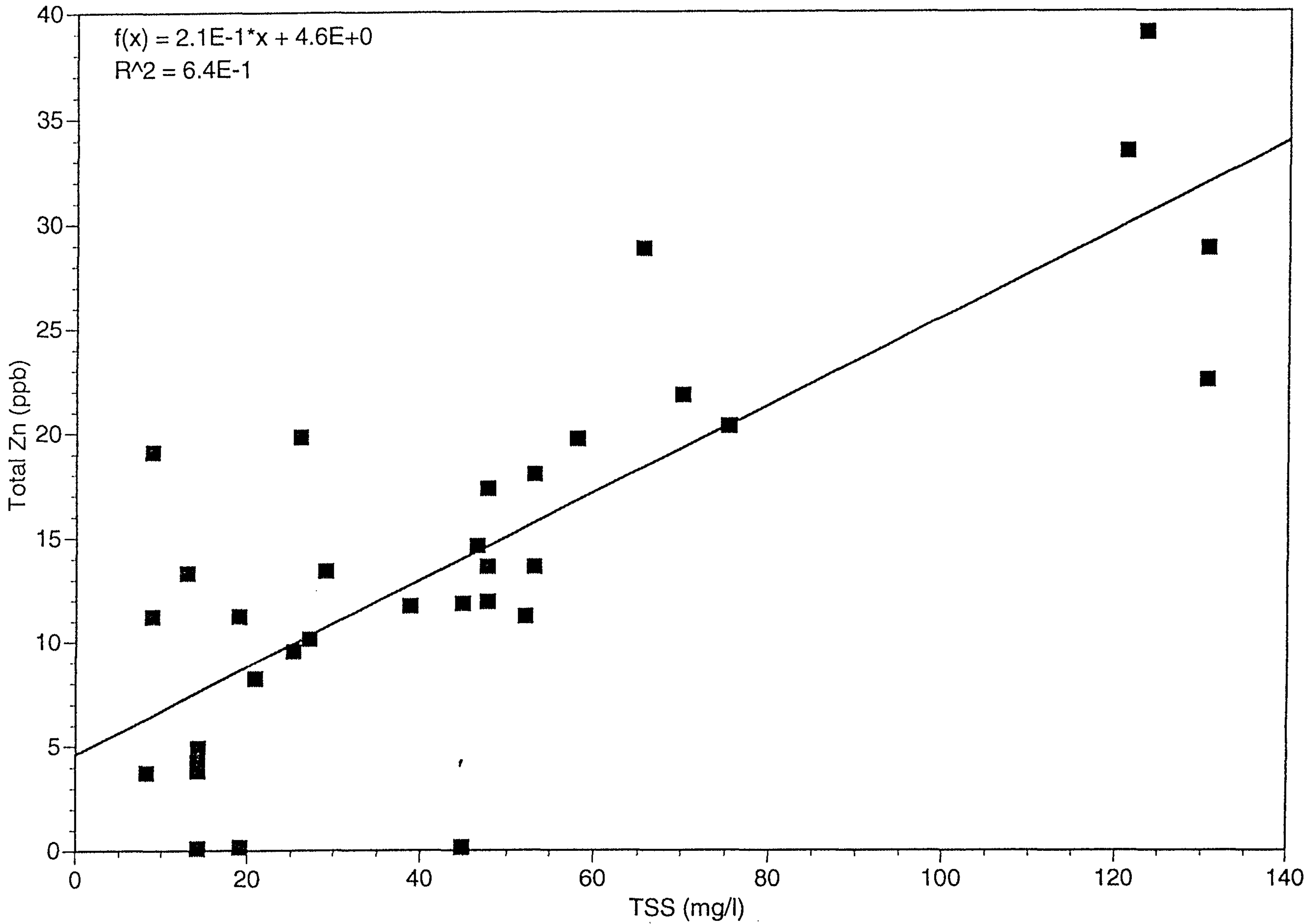


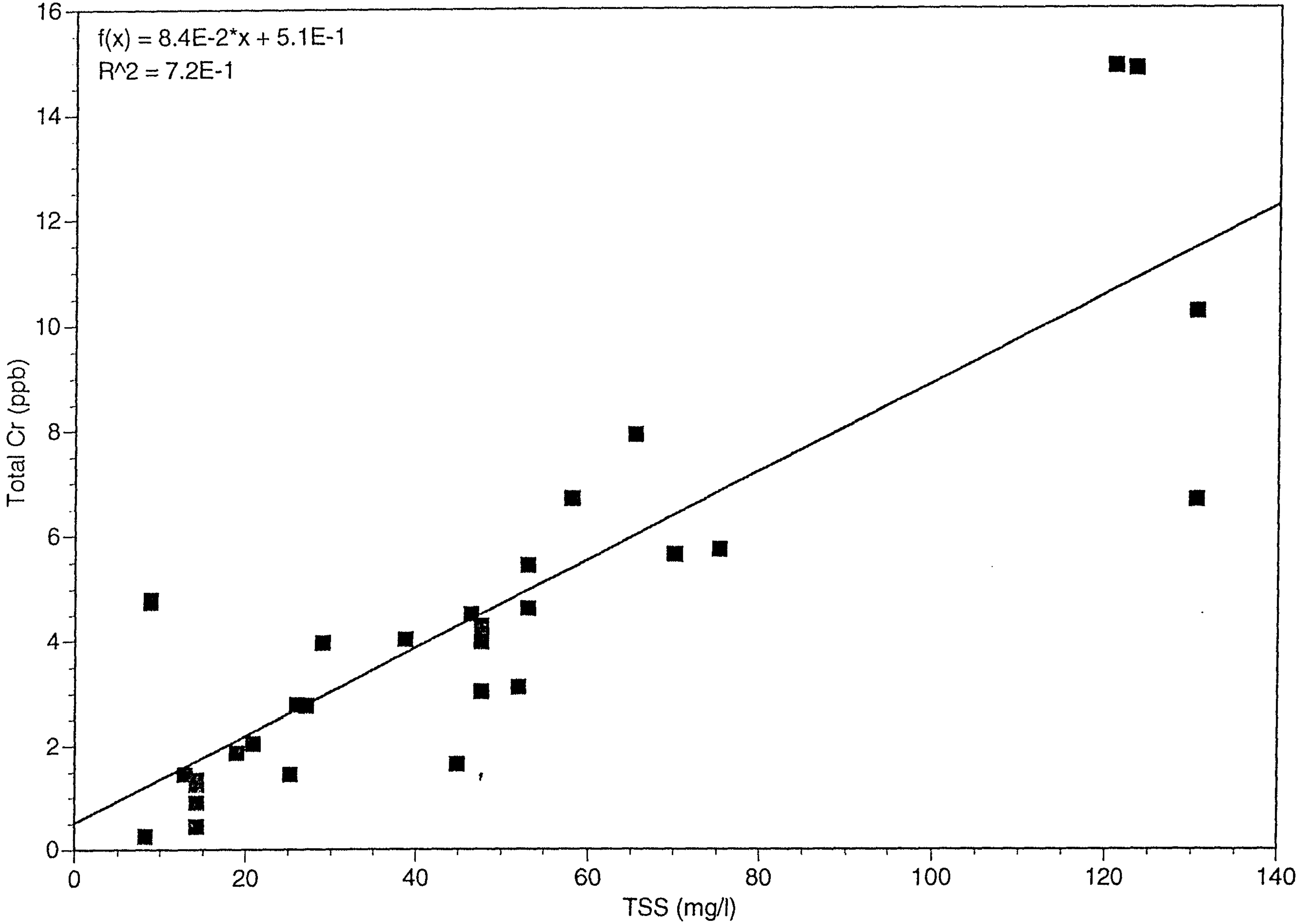
Fig 9.

BPTCP 1993-1994~~Flow~~ TSS



> Fig 10

BPTCP 1993-1994/[redacted] TSS



> Fig 11

BPTCP 1993-1994/ ~~[illegible]~~ TSS

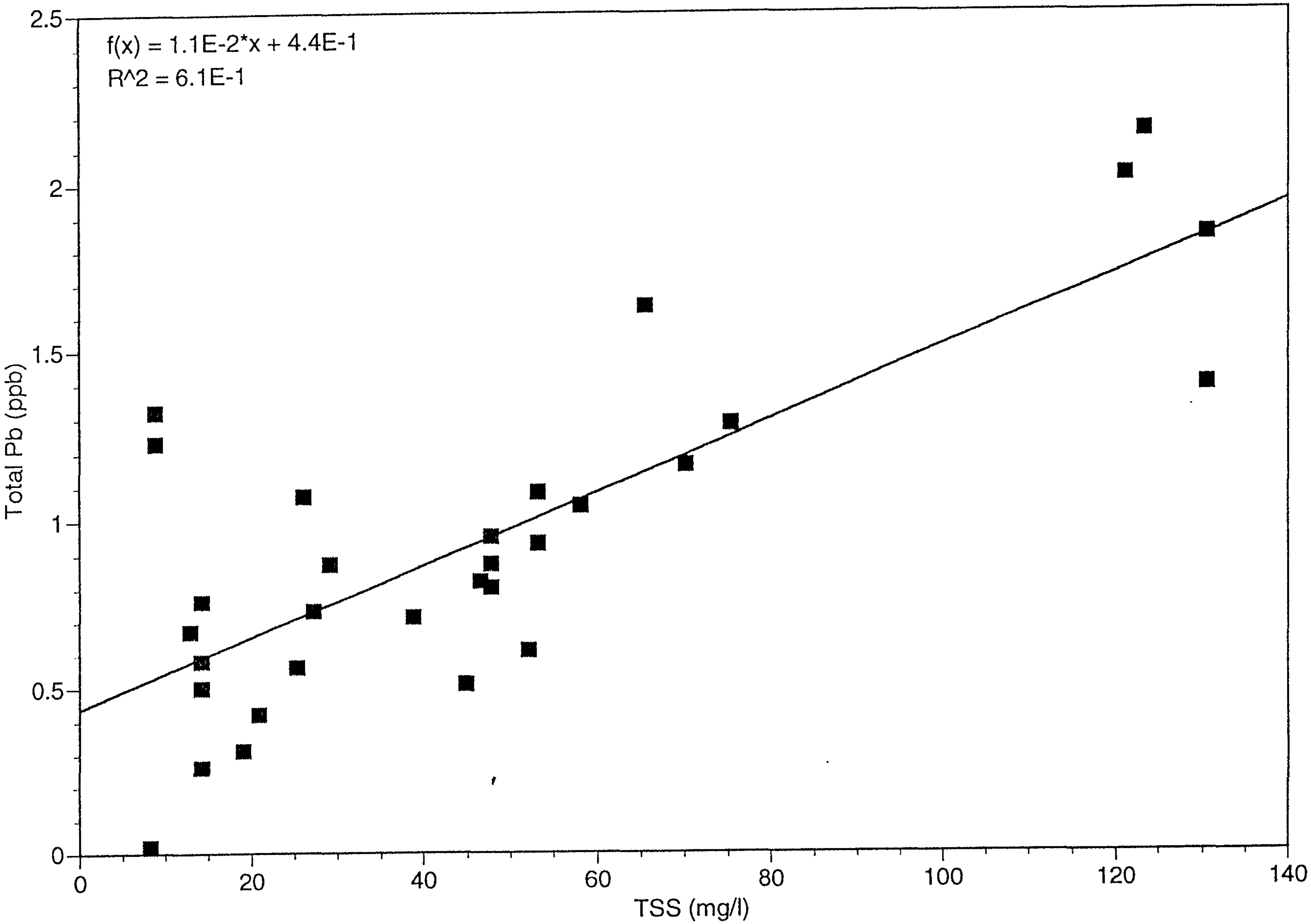
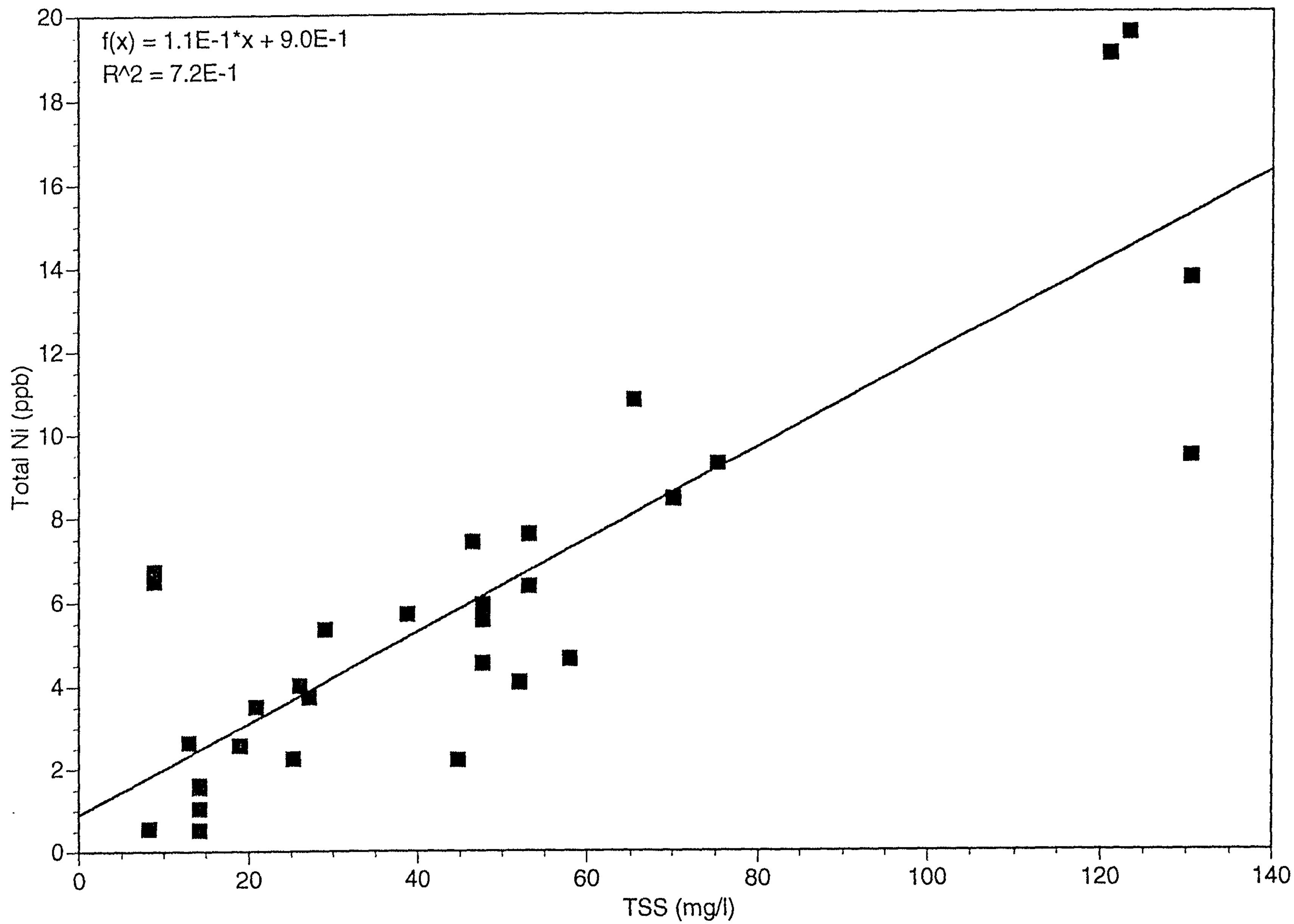


Fig 12

BPTCP 1993-1994/[redacted] TSS



> Fig 13

D-042752

D — 0 4 2 7 5 2

D-042753

BPTCP 1993-1994/Flow

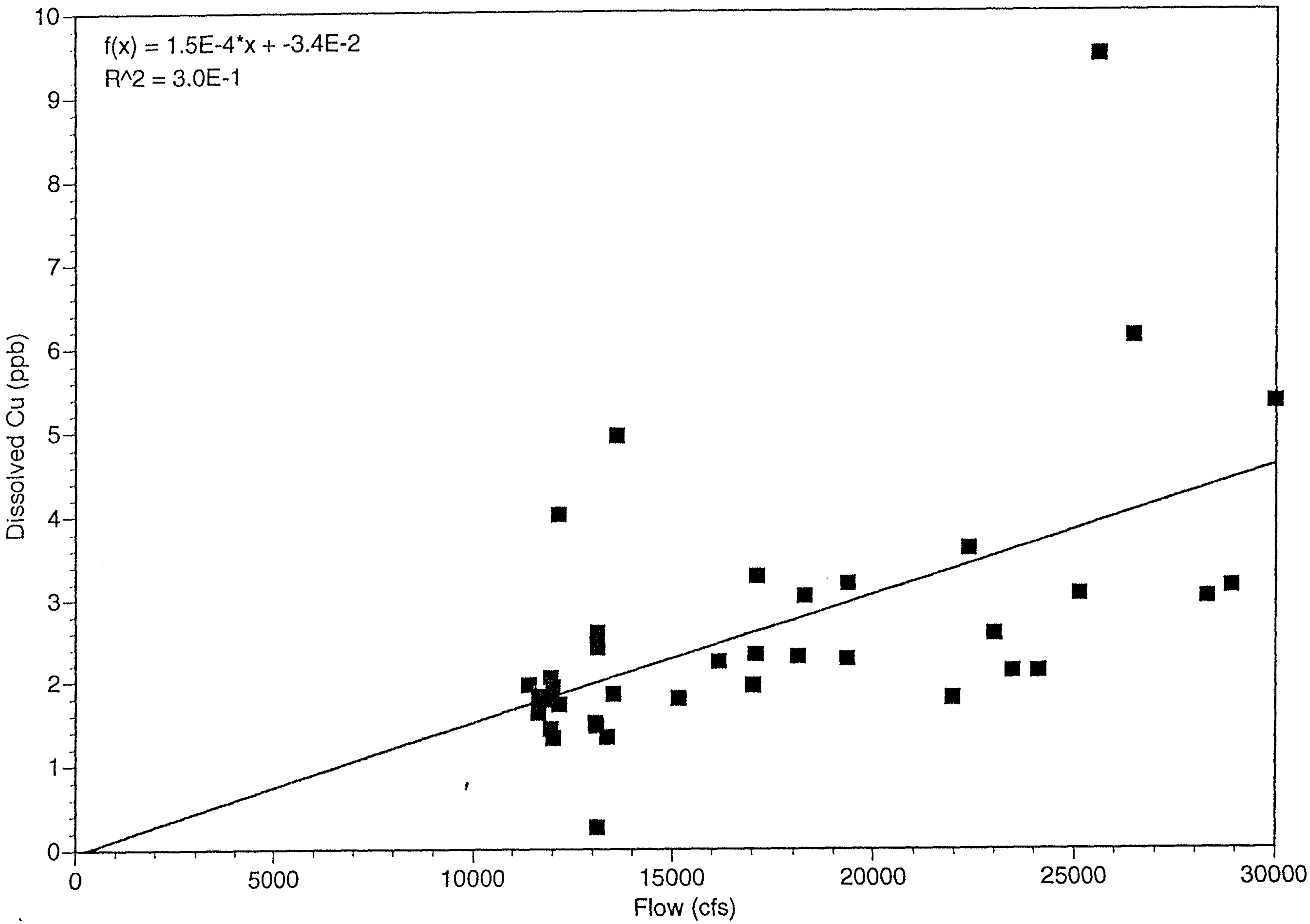
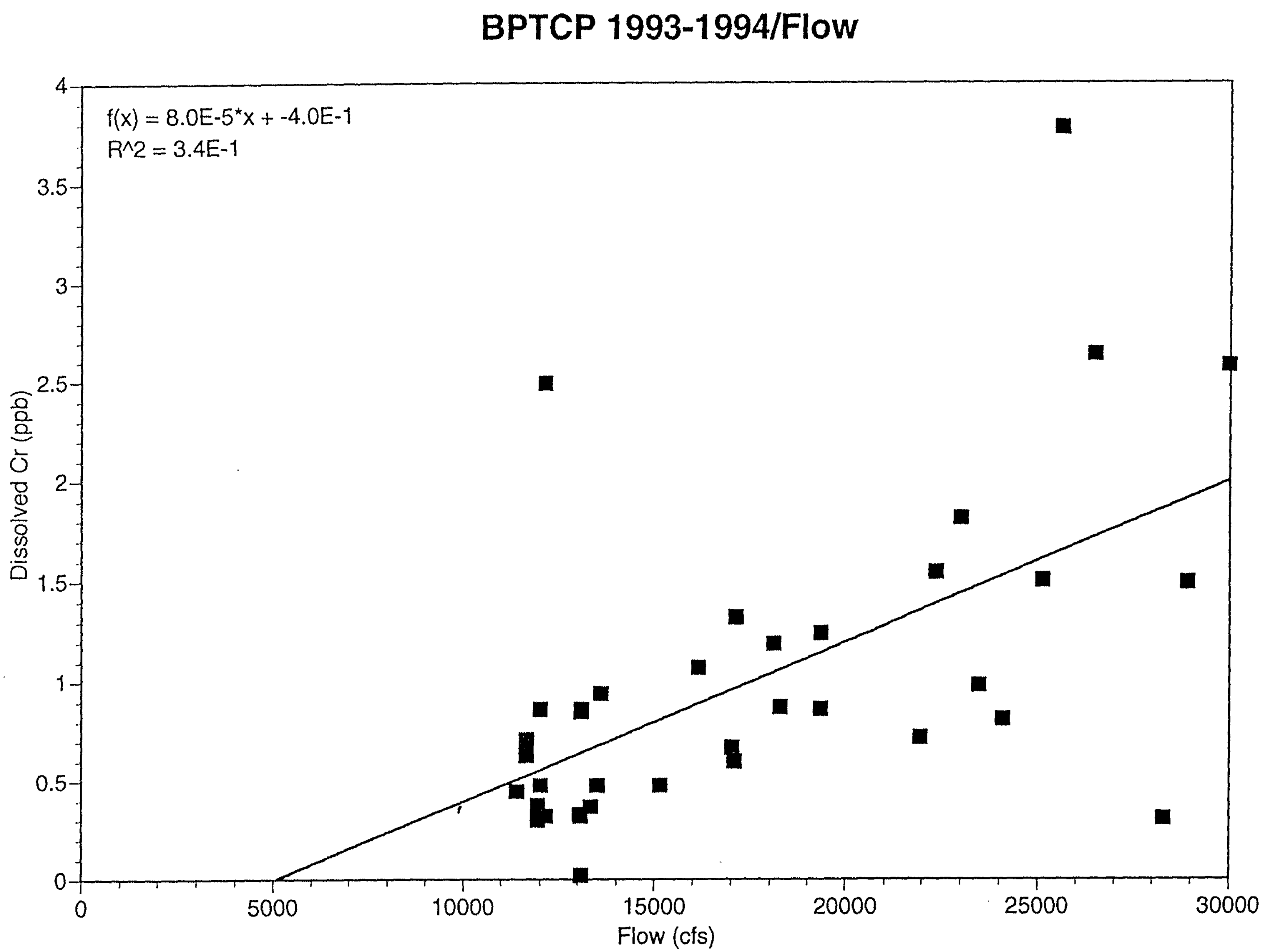


Fig 14

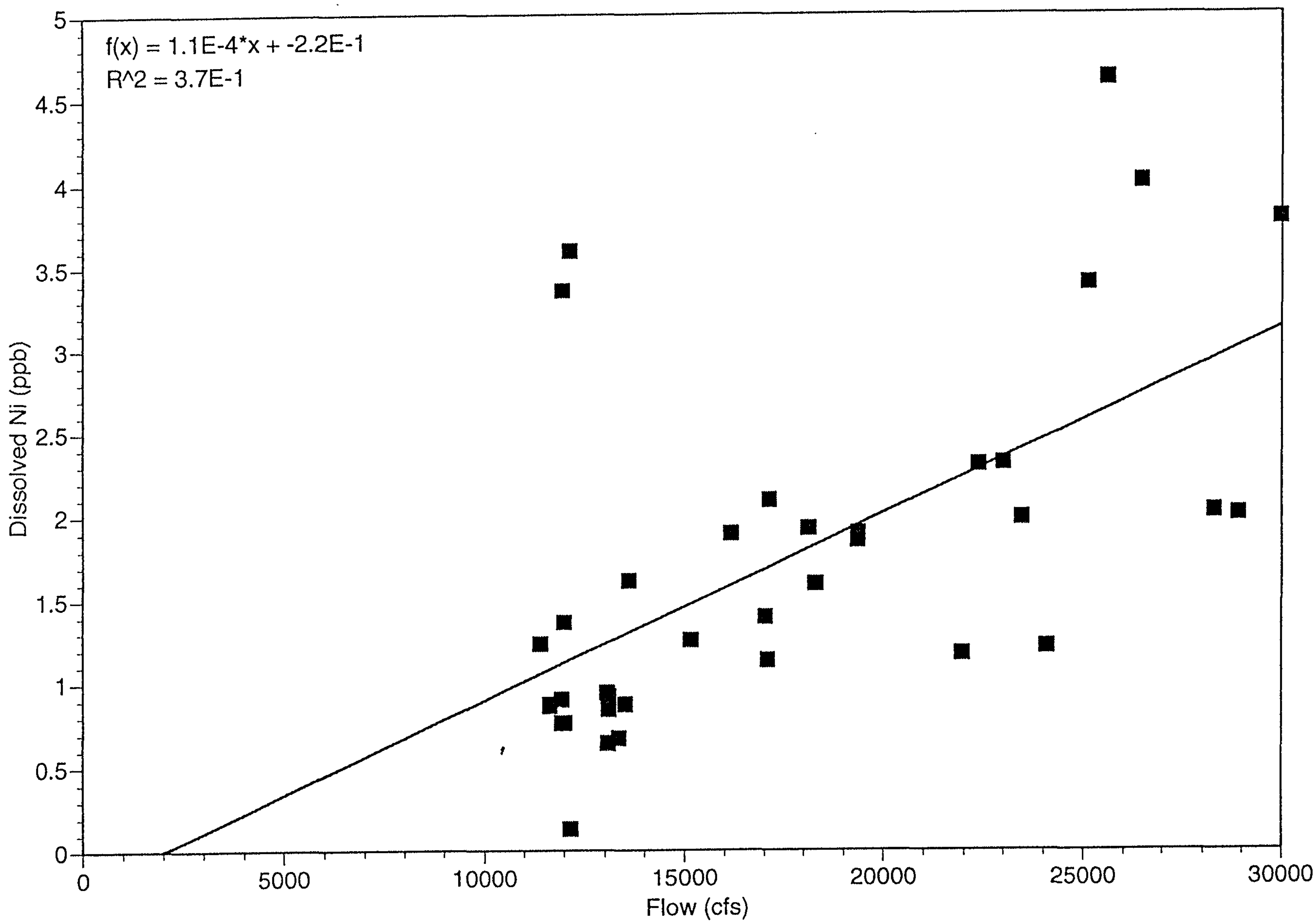
D — 0 4 2 7 5 3


BPTCP 1993-1994/Flow
f(x) = 8.0E-5*x + -4.0E-1
R^2 = 3.4E-1
Dissolved Cr (ppb)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
5000
10000
15000
20000
25000
30000
Flow (cfs)

→ Fig 15

D-042755

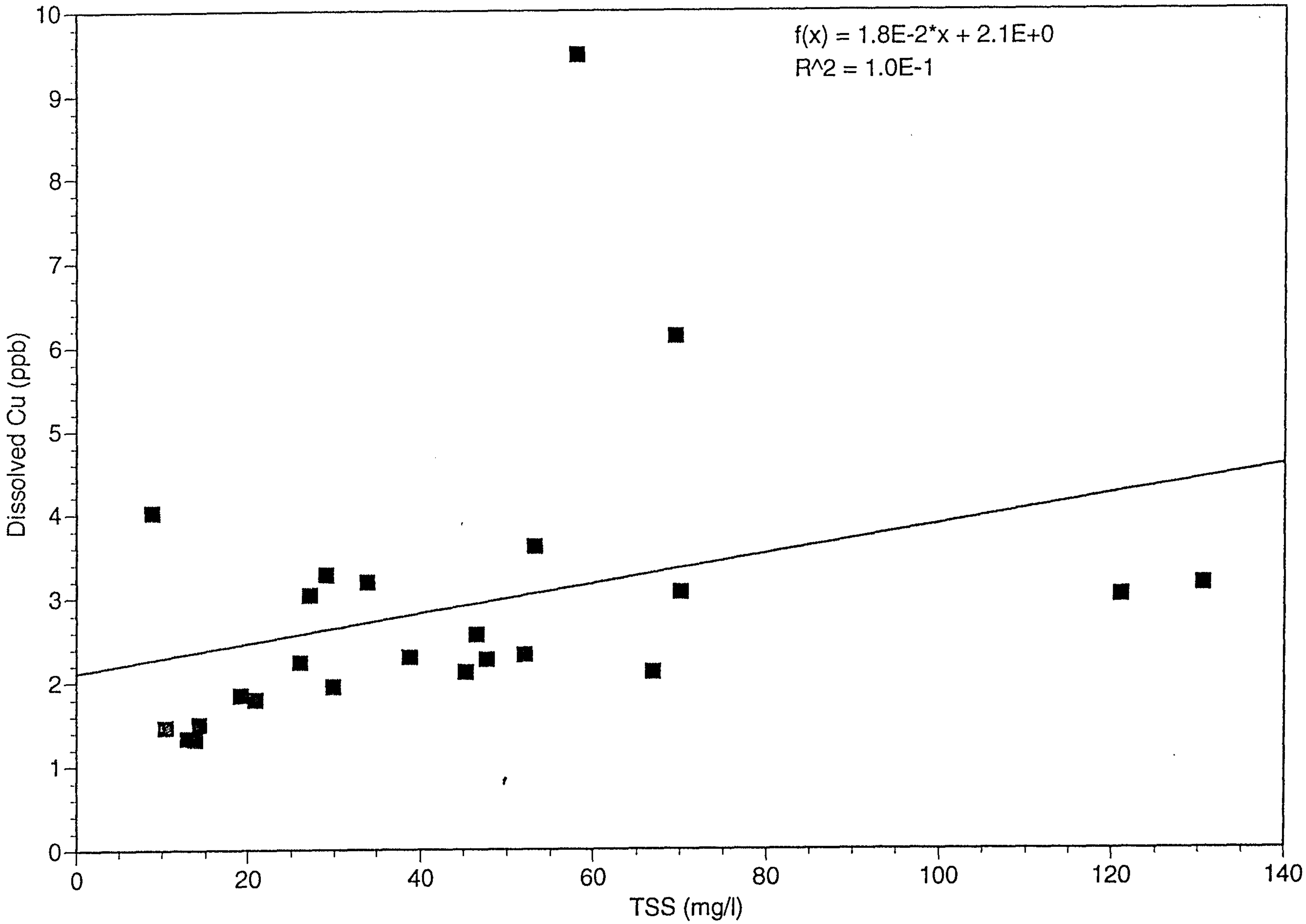
BPTCP 1993-1994/Flow



-> Fig 10

D-042755

BPTCP 1993-1994/~~Flow~~ TSS

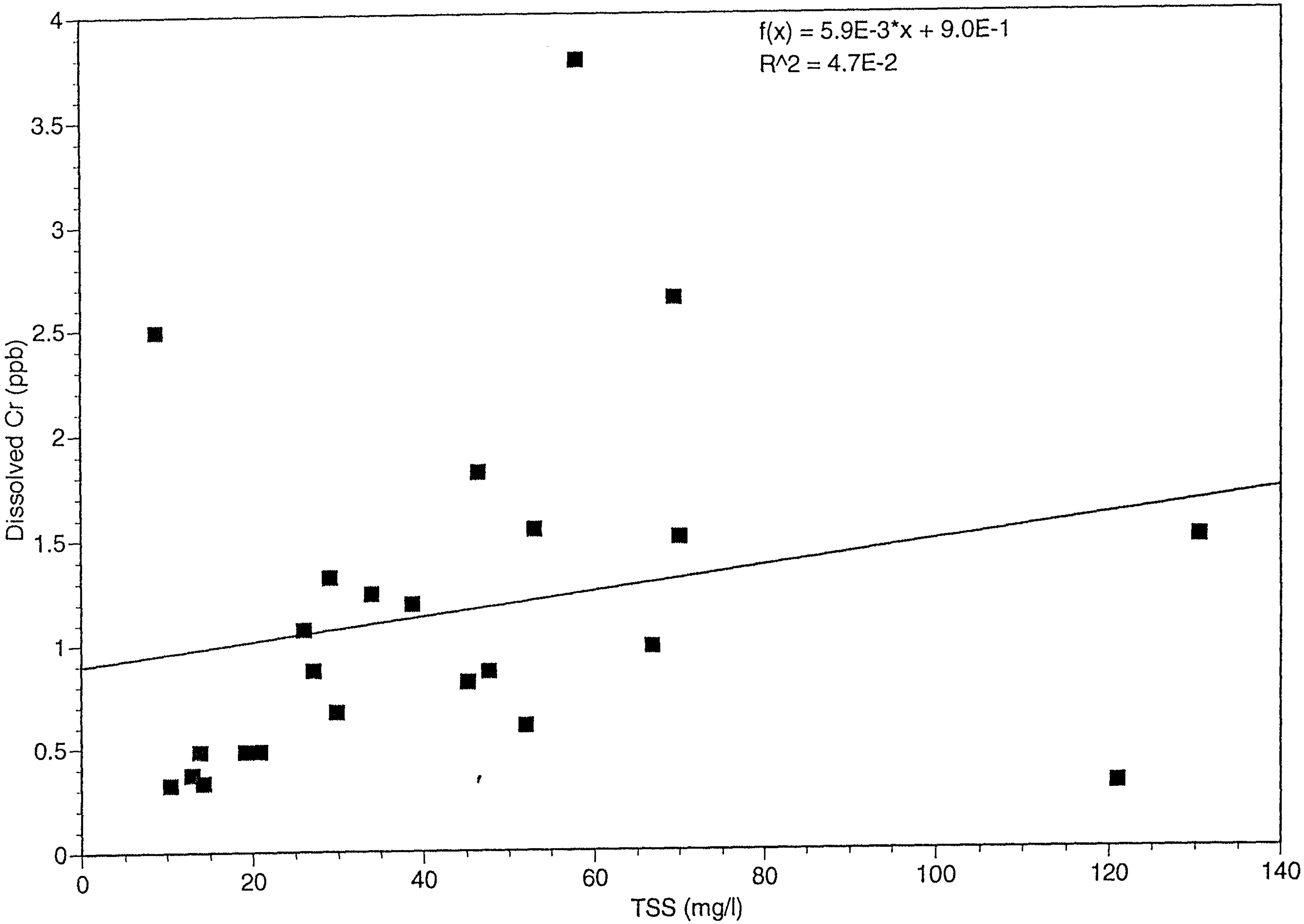


> Fig 17

D-042756

D — 0 4 2 7 5 6

BPTCP 1993-1994/[redacted] TSS

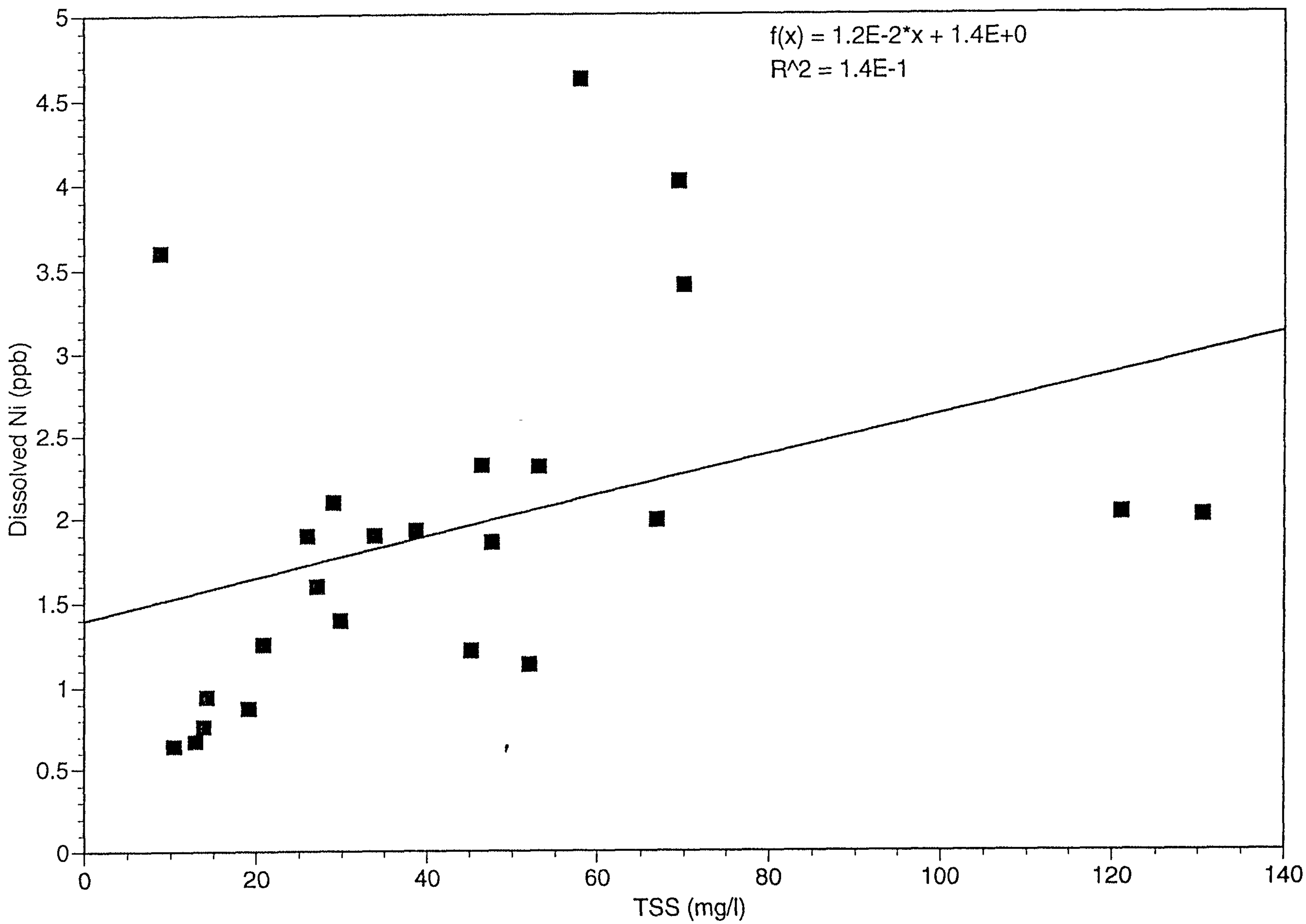


→ Fig 18

D-042757

D-042757

BPTCP 1993-1994/[redacted] TSS



.19

BPTCP 1993-1994/TCr vs. DCr

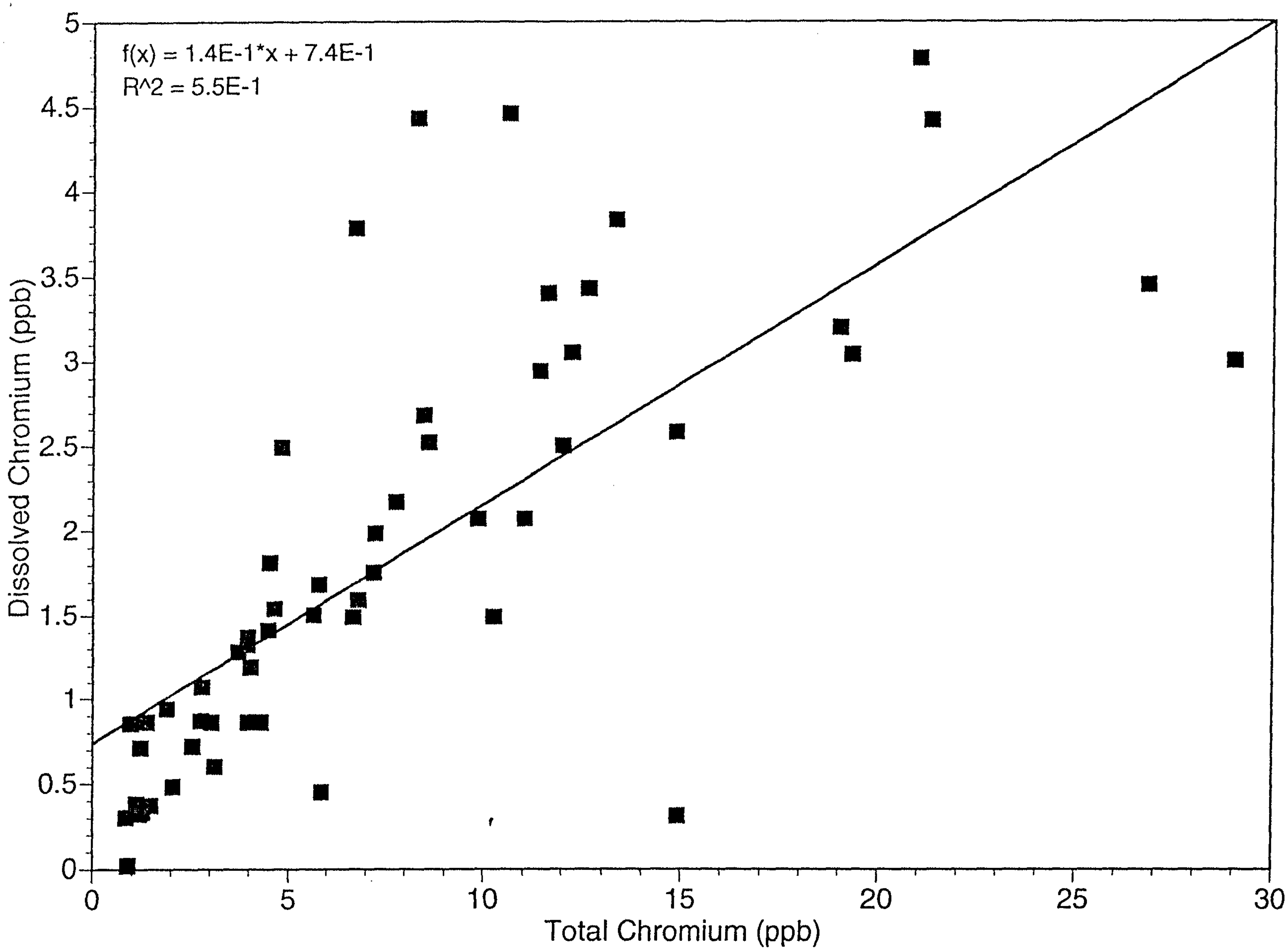


Fig 20

D-042759

D — 0 4 2 7 5 9

BPTCP 1993-1994/TPb vs. DPb

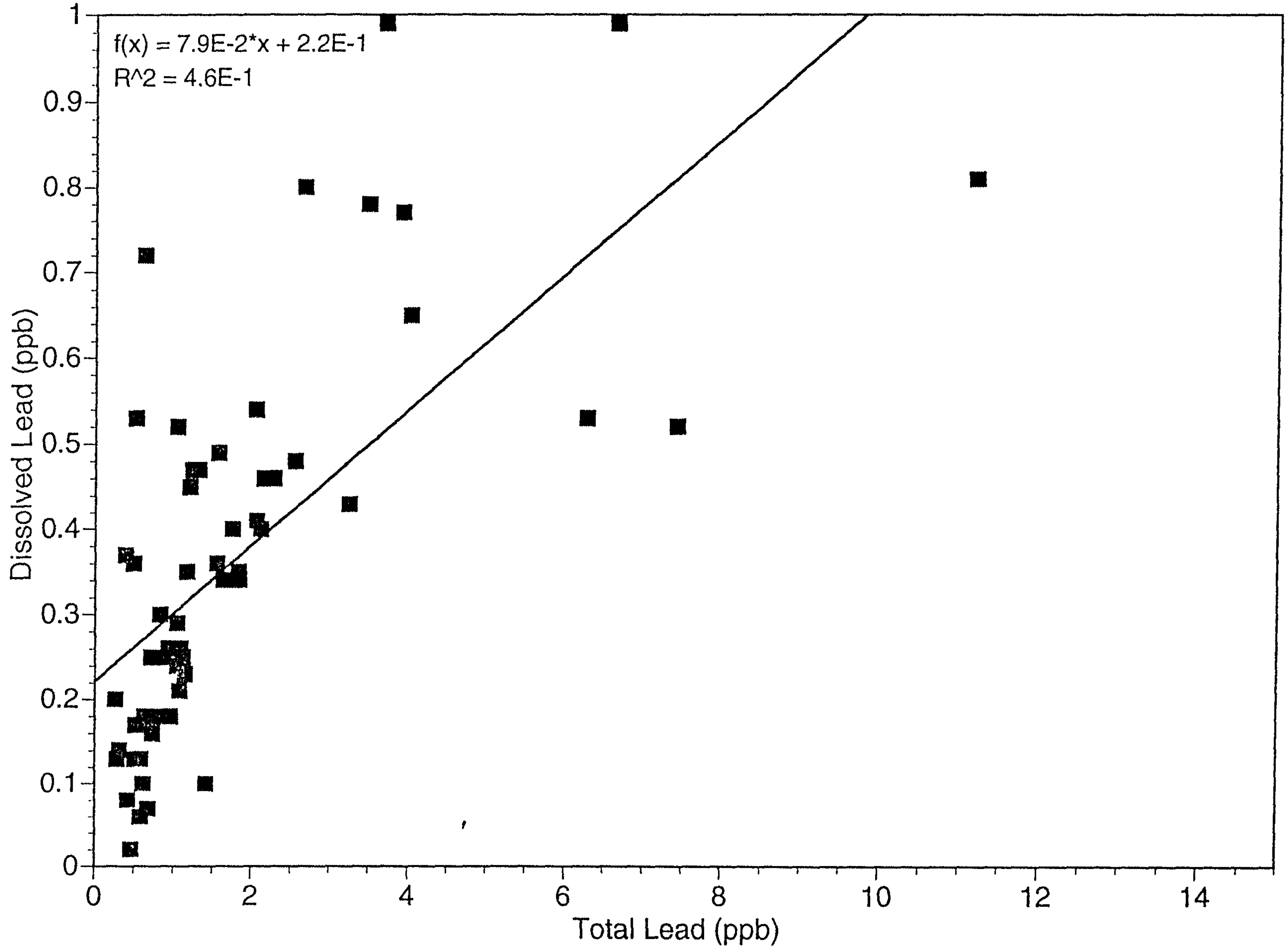


Fig 21

D-042760

BPTCP 1994-1995/Flow

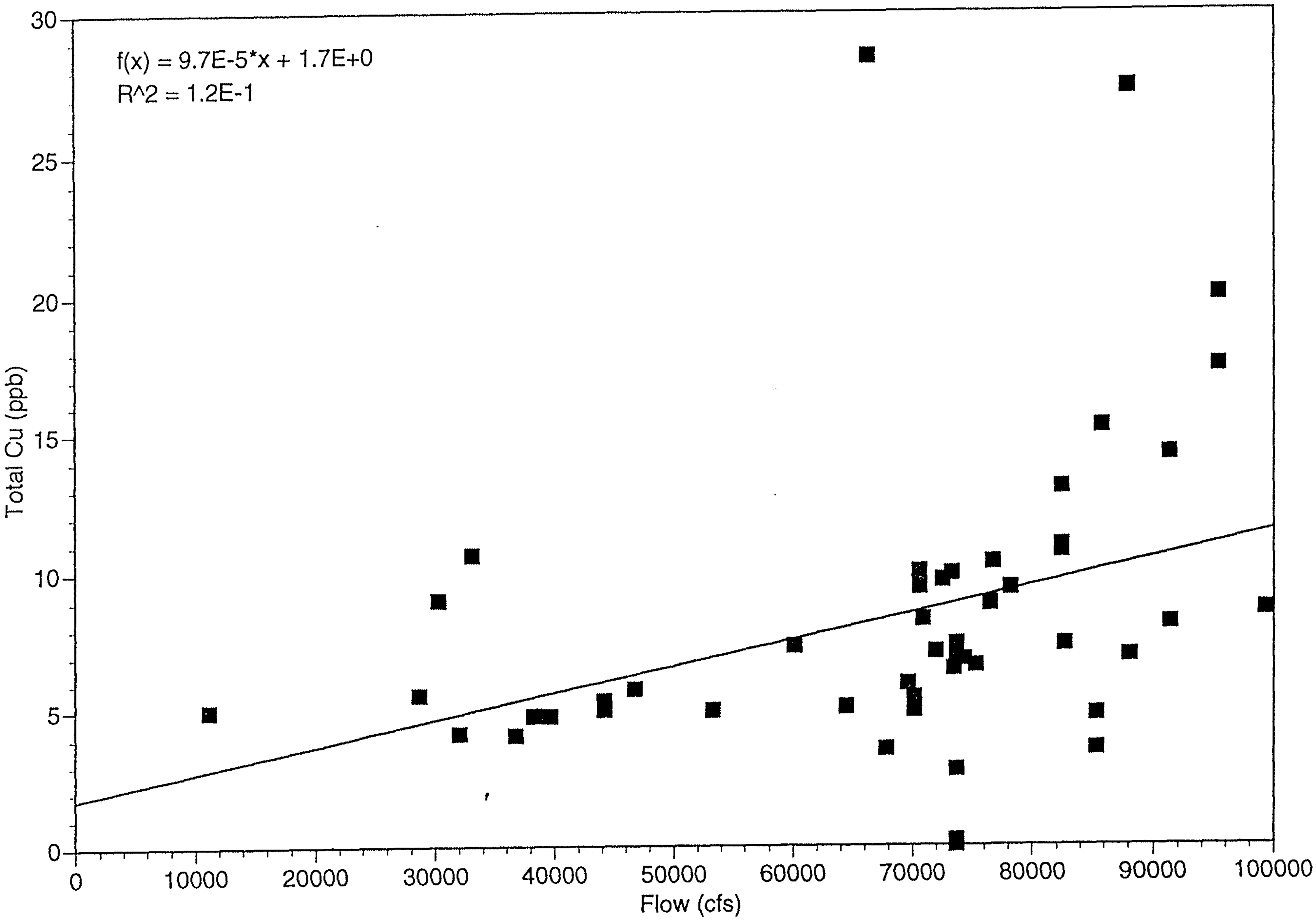
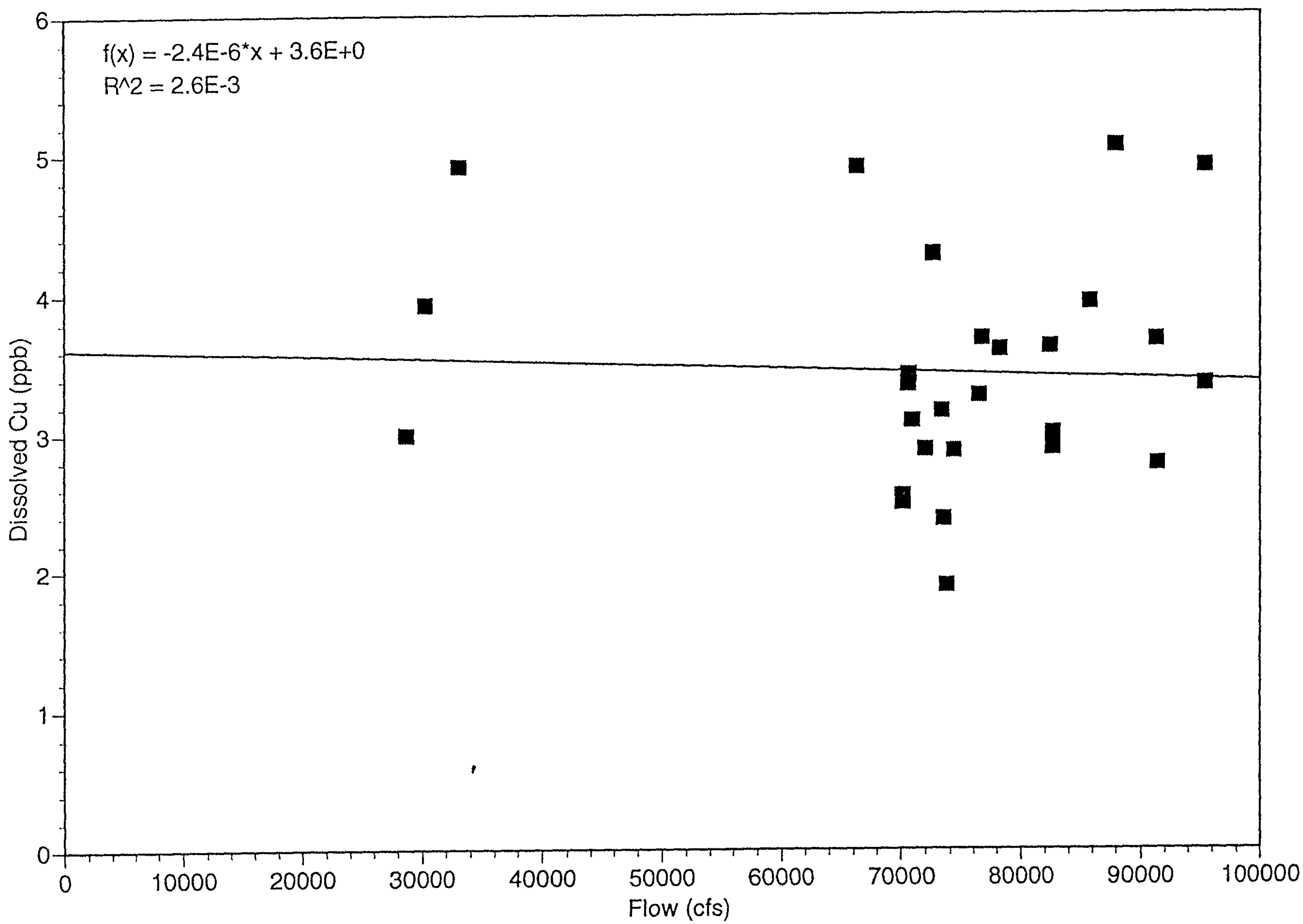


Fig. 2

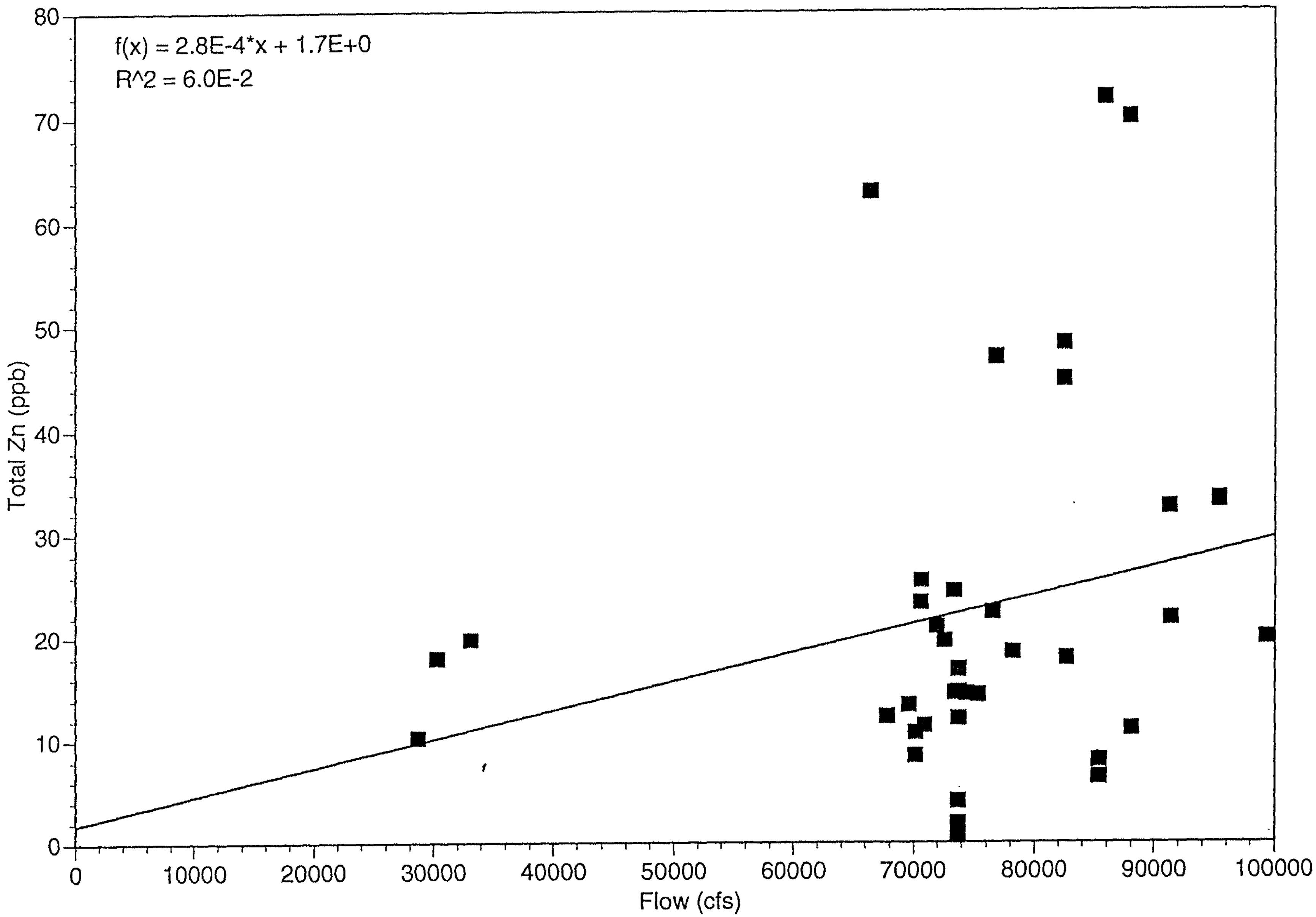
BPTCP 1994-1995/Flow



D-042762

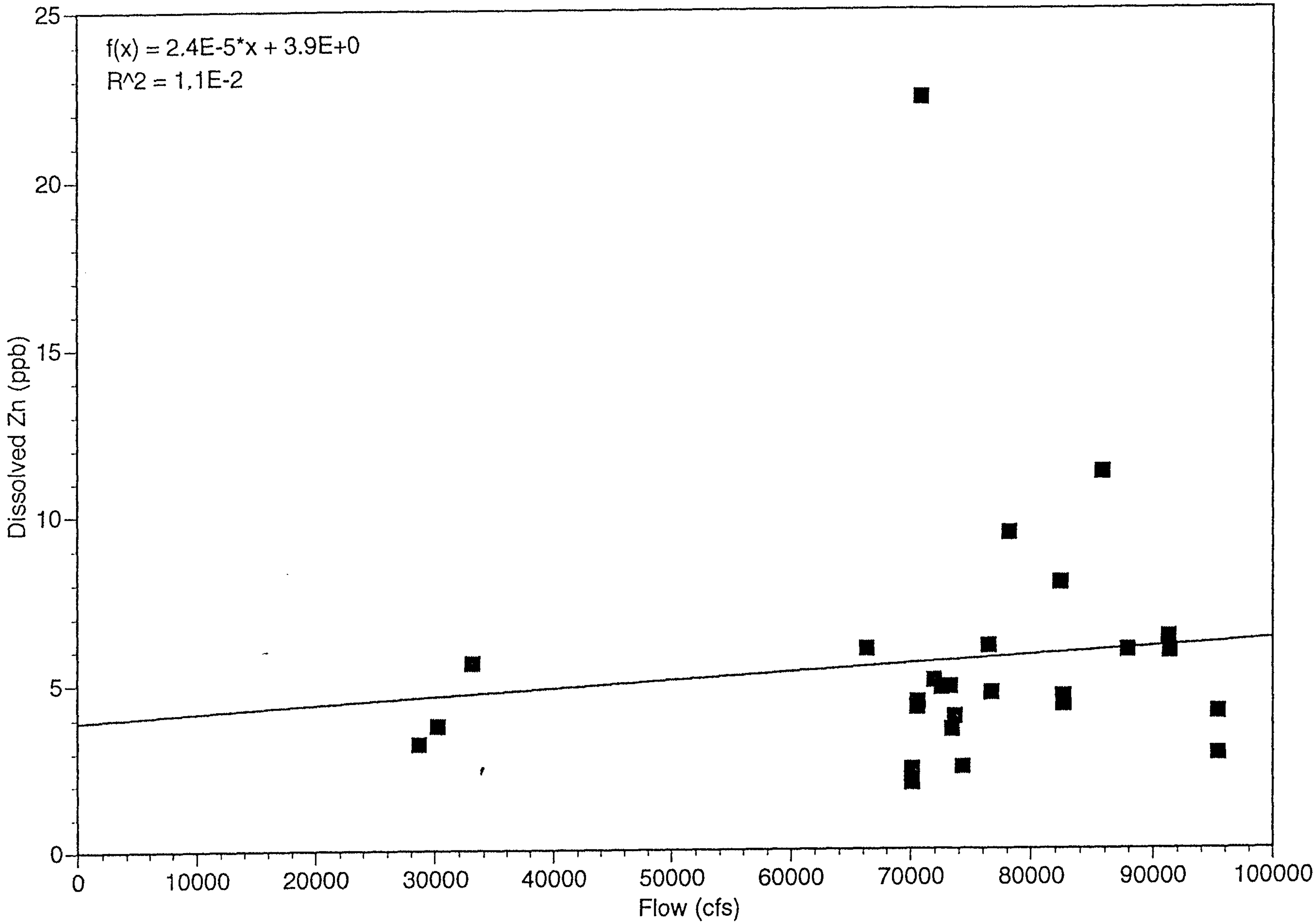
D-042762

BPTCP 1994-1995/Flow



→ Fig 24

BPTCP 1994-1995/Flow

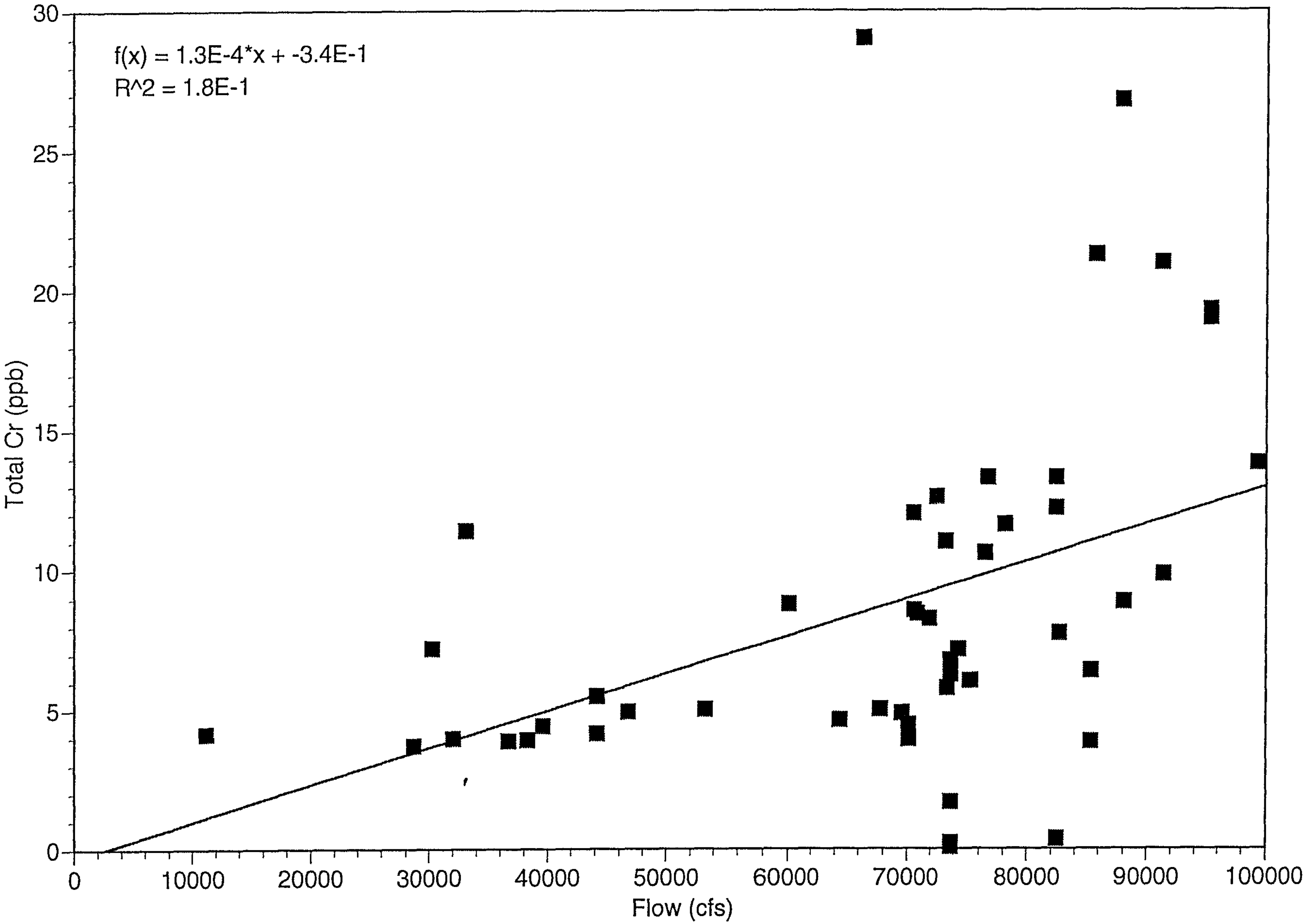


→ Fig 25

D-042764

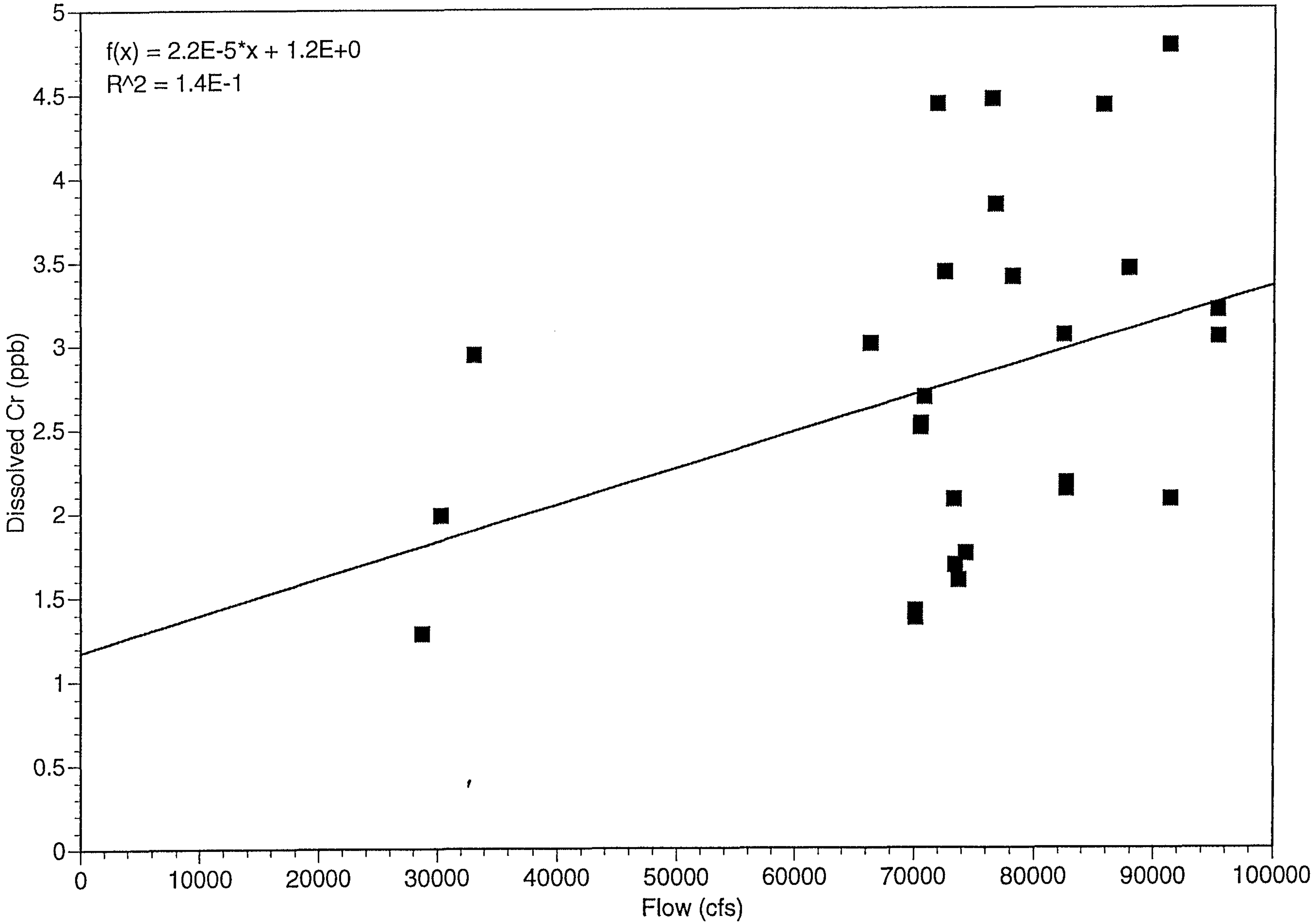
D-042764

BPTCP 1994-1995/Flow



→ Fig 26

BPTCP 1994-1995/Flow

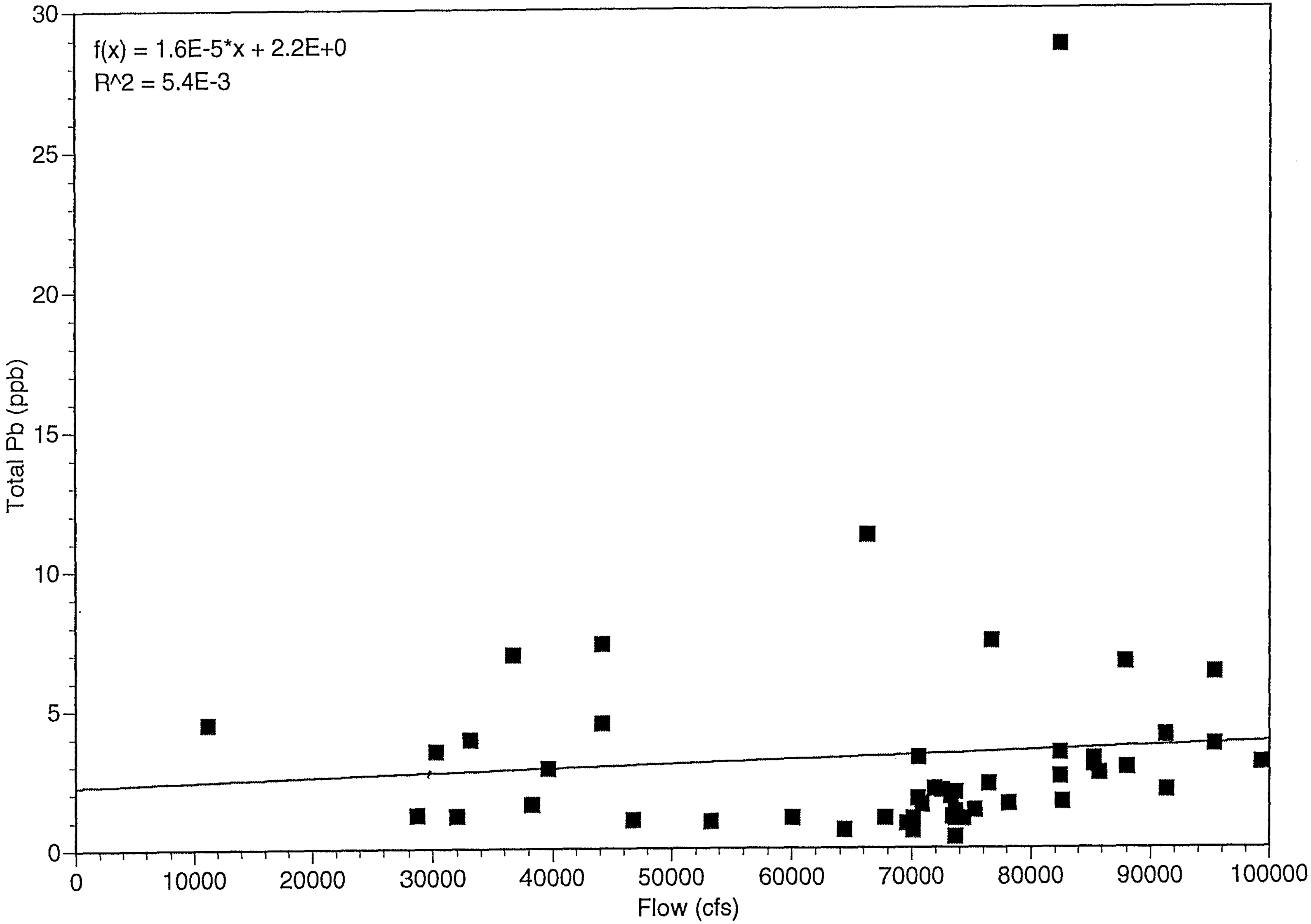


→ Fig 27

D-042766

D-042766

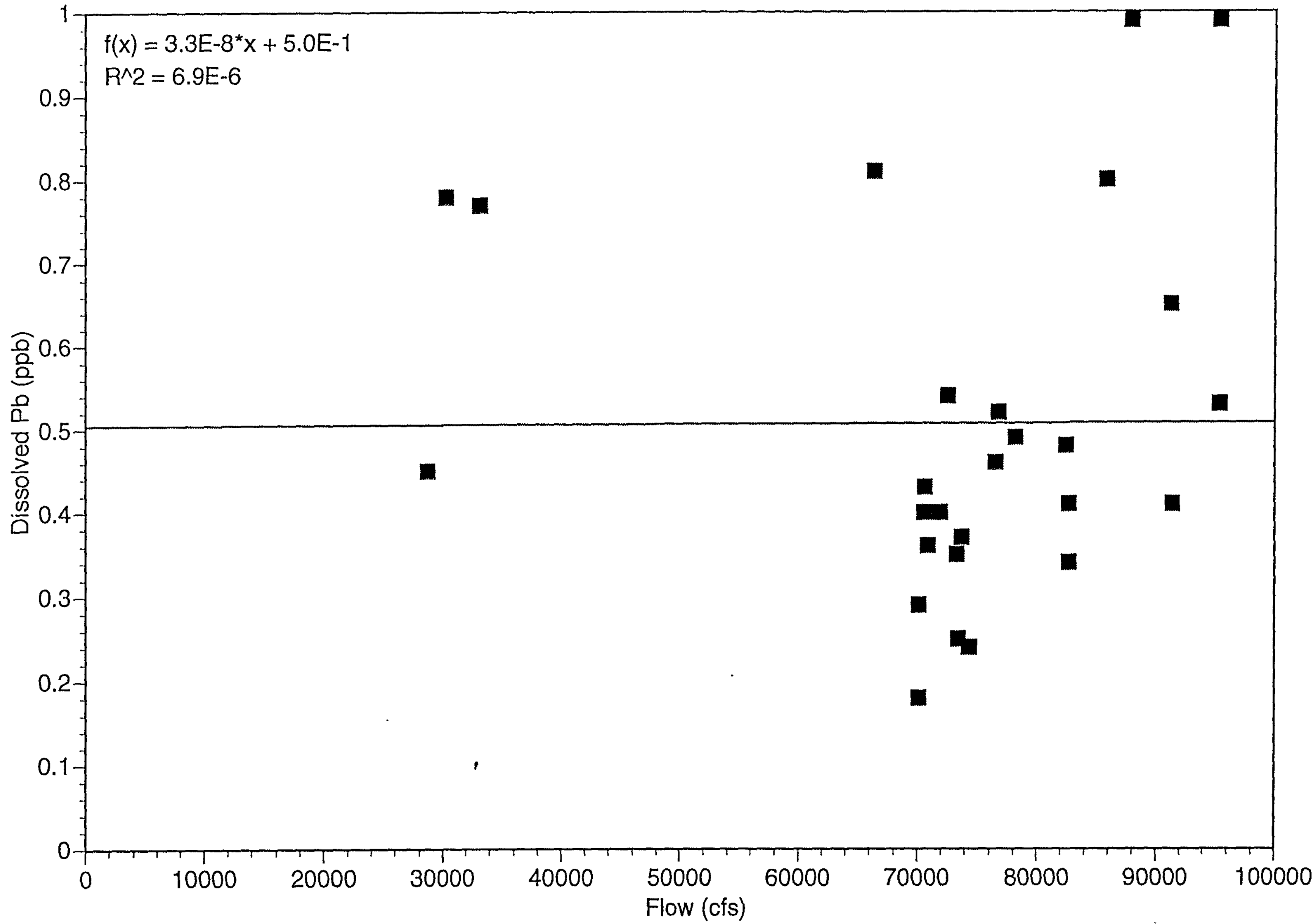
BPTCP 1994-1995/Flow



→ Fig 28

D-042767

BPTCP 1994-1995/Flow



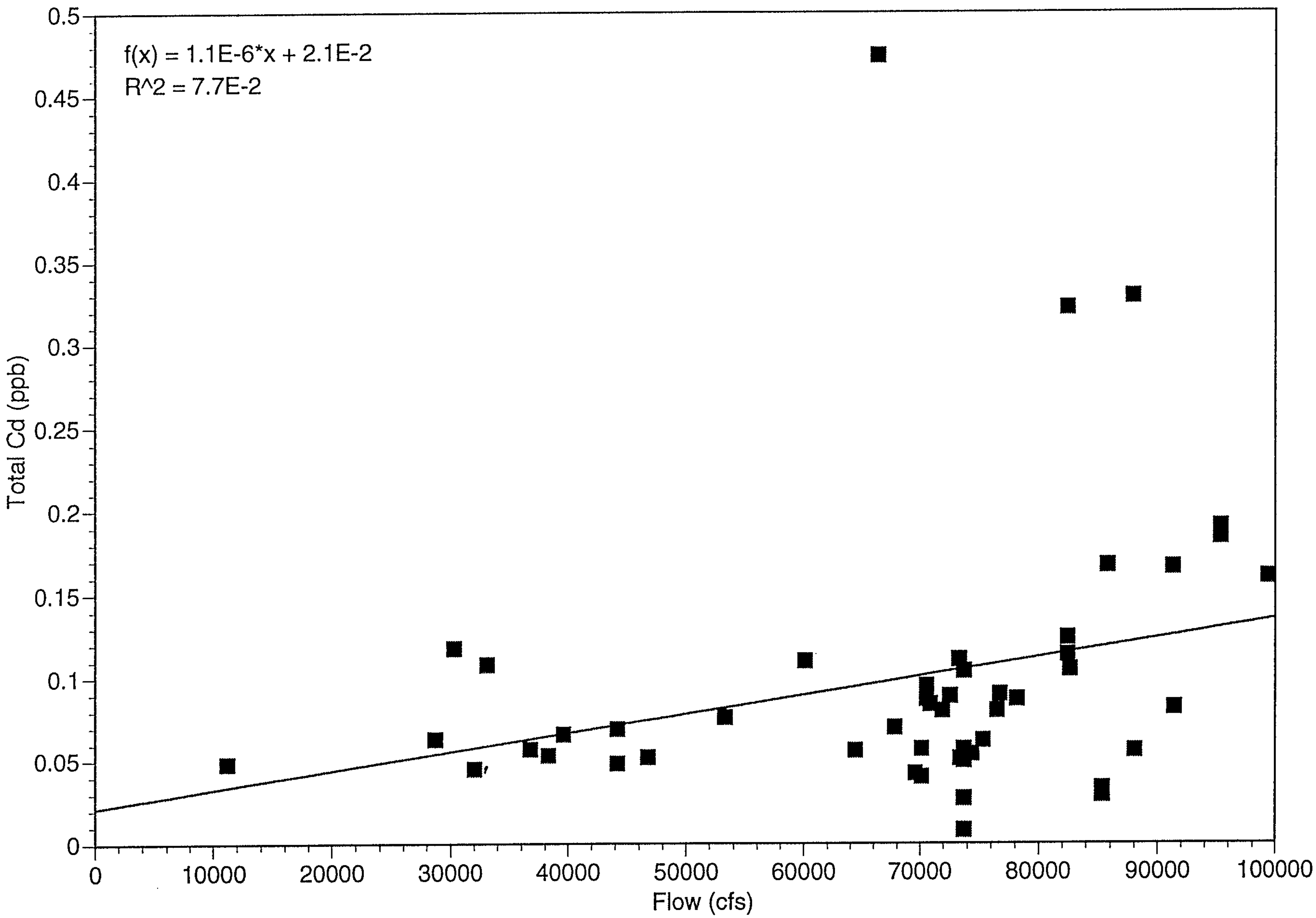
00

→ Fig 29

D-042768

D-042768

BPTCP 1994-1995/Flow



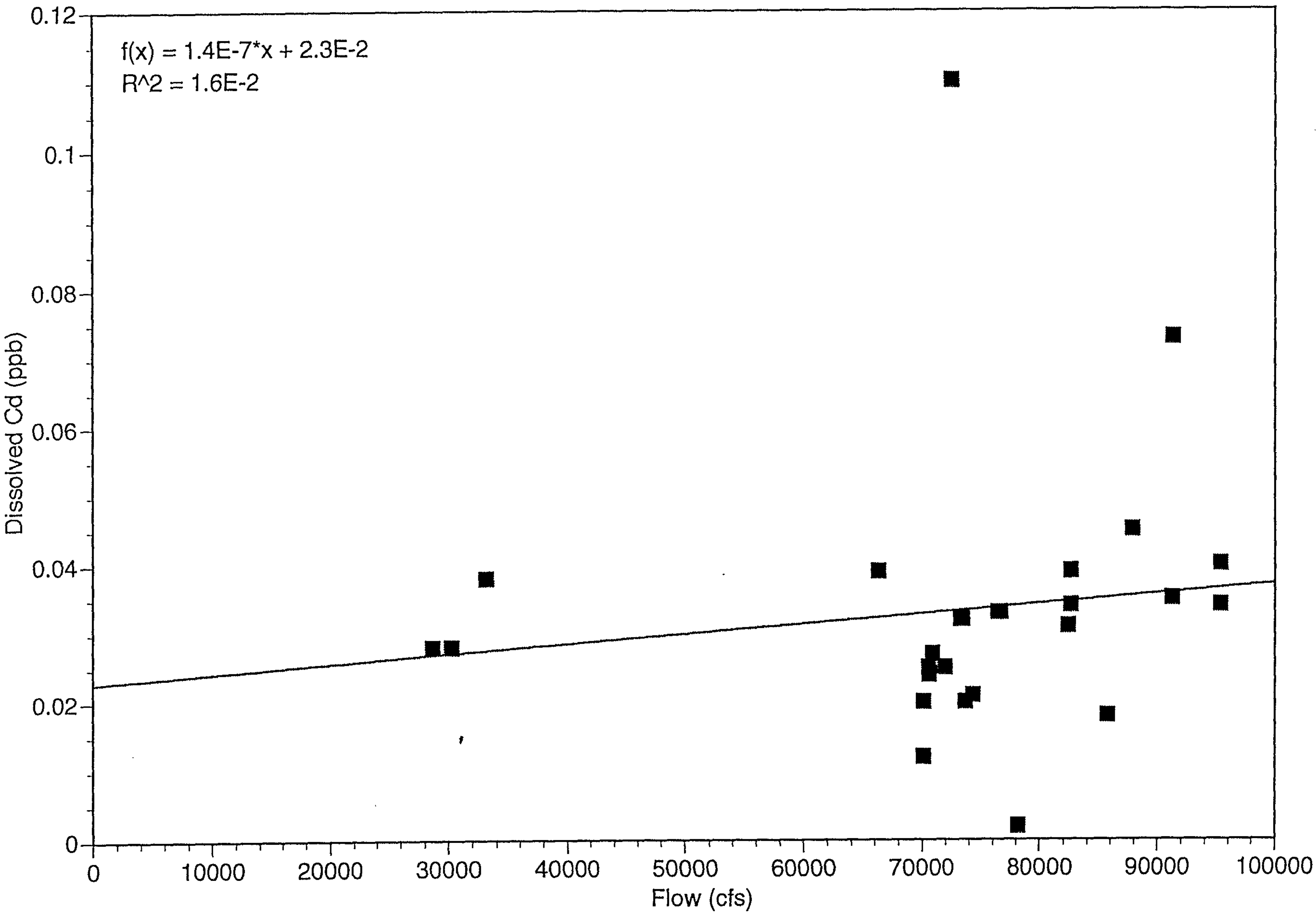
→ Fig 30

D-042769

D-042769

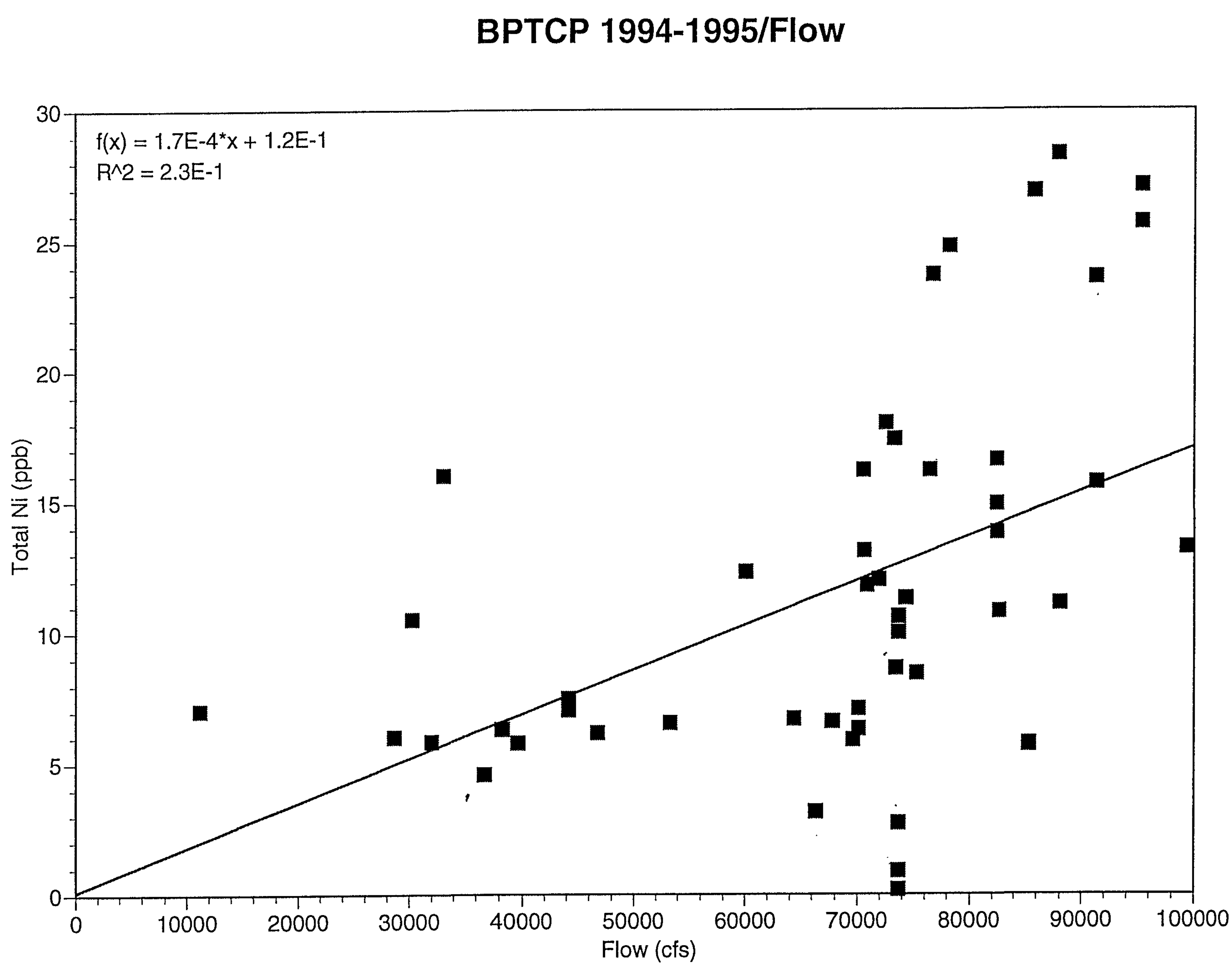
D-042770

BPTCP 1994-1995/Flow



D—042770

→ Fig 31



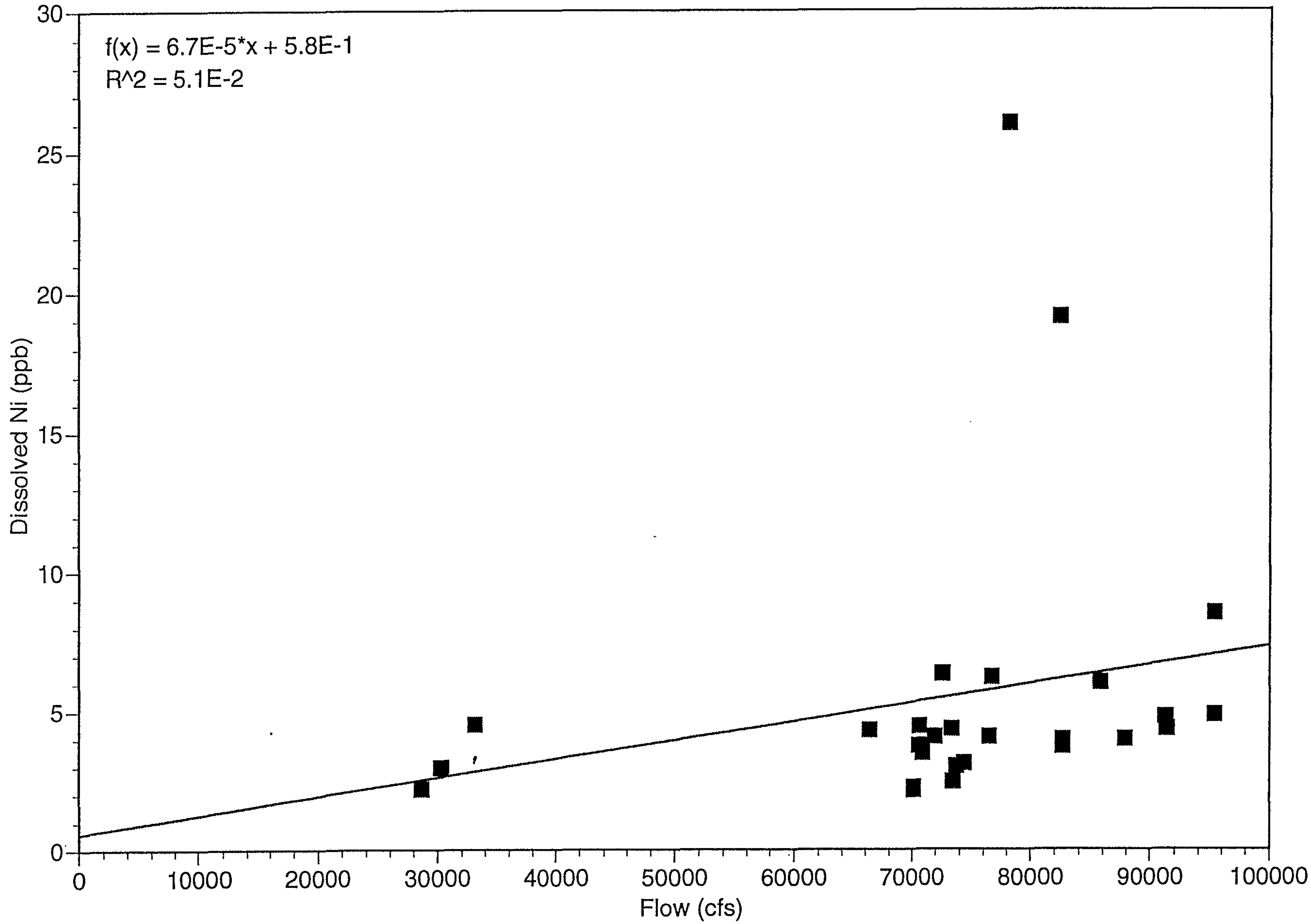
0

→ Fig 32

D-042771

D-042771

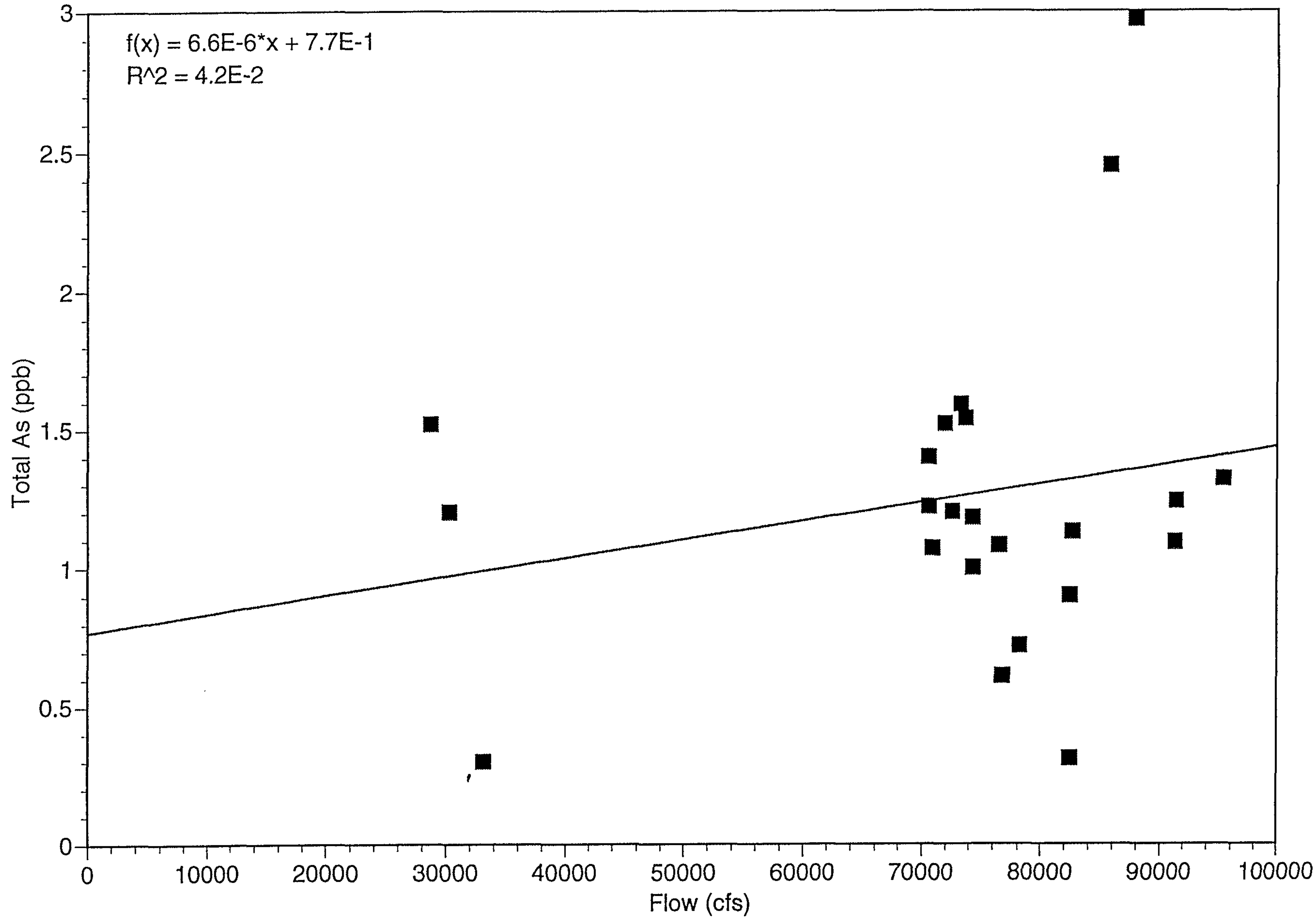
BPTCP 1994-1995/Flow



D-042772

→ Fig 33

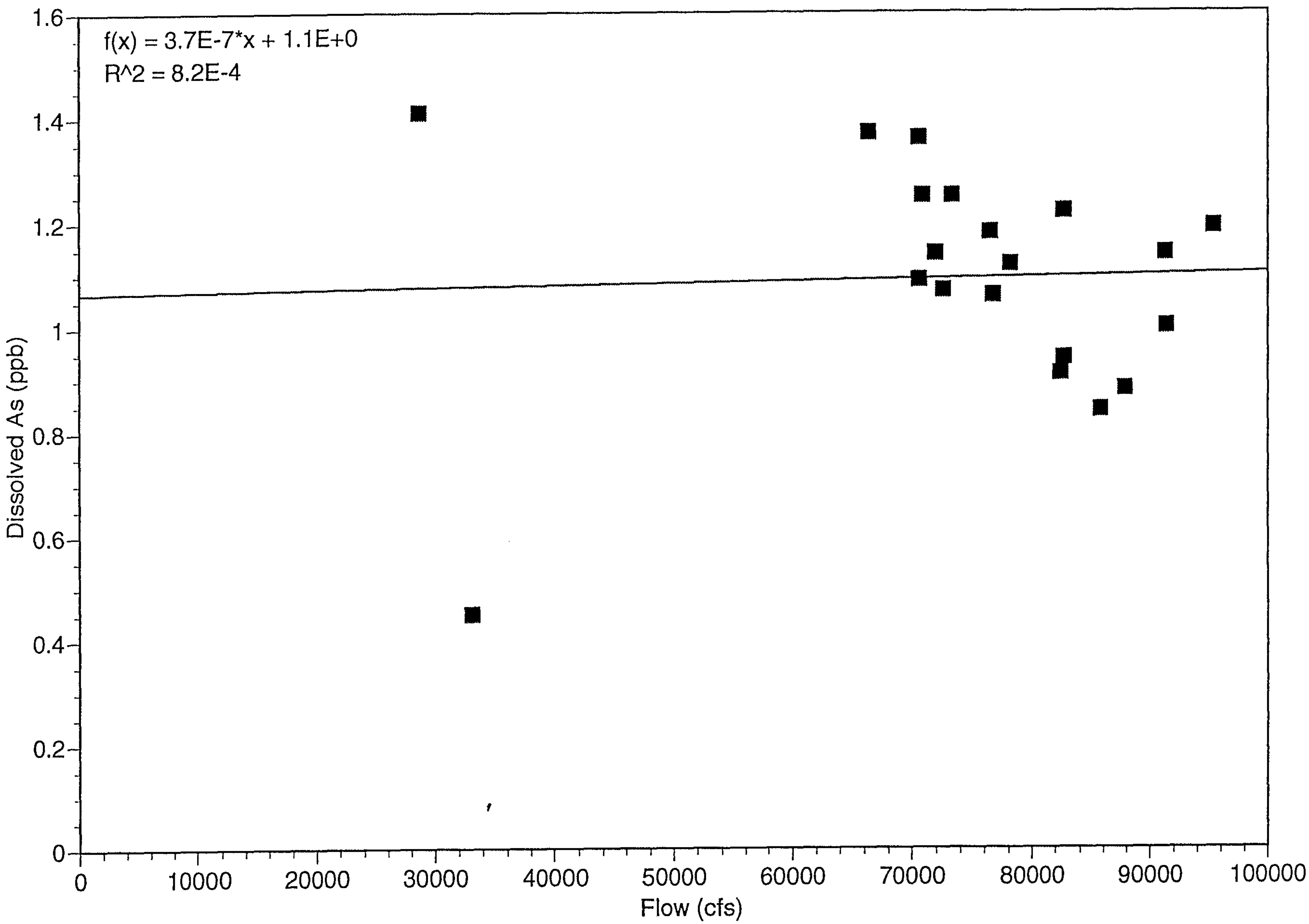
BPTCP 1994-1995/Flow



→ Fig 34

D-042774

BPTCP 1994-1995/Flow



→ Fig 35

D — 0 4 2 7 7 4

D-042775

BPTCP 1994-1995/TSS

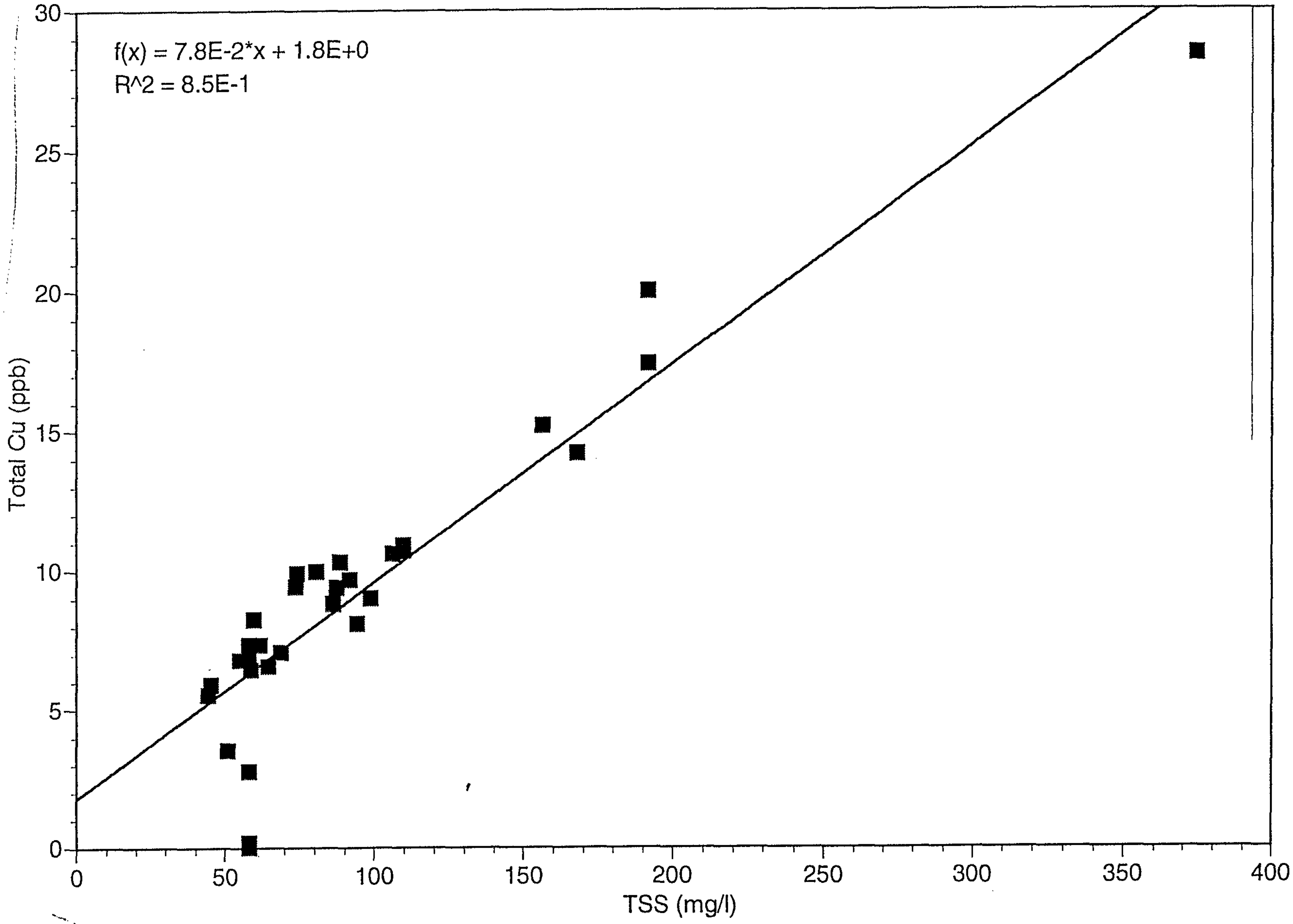


Fig 36

D-042775

BPTCP 1994-1995/TSS

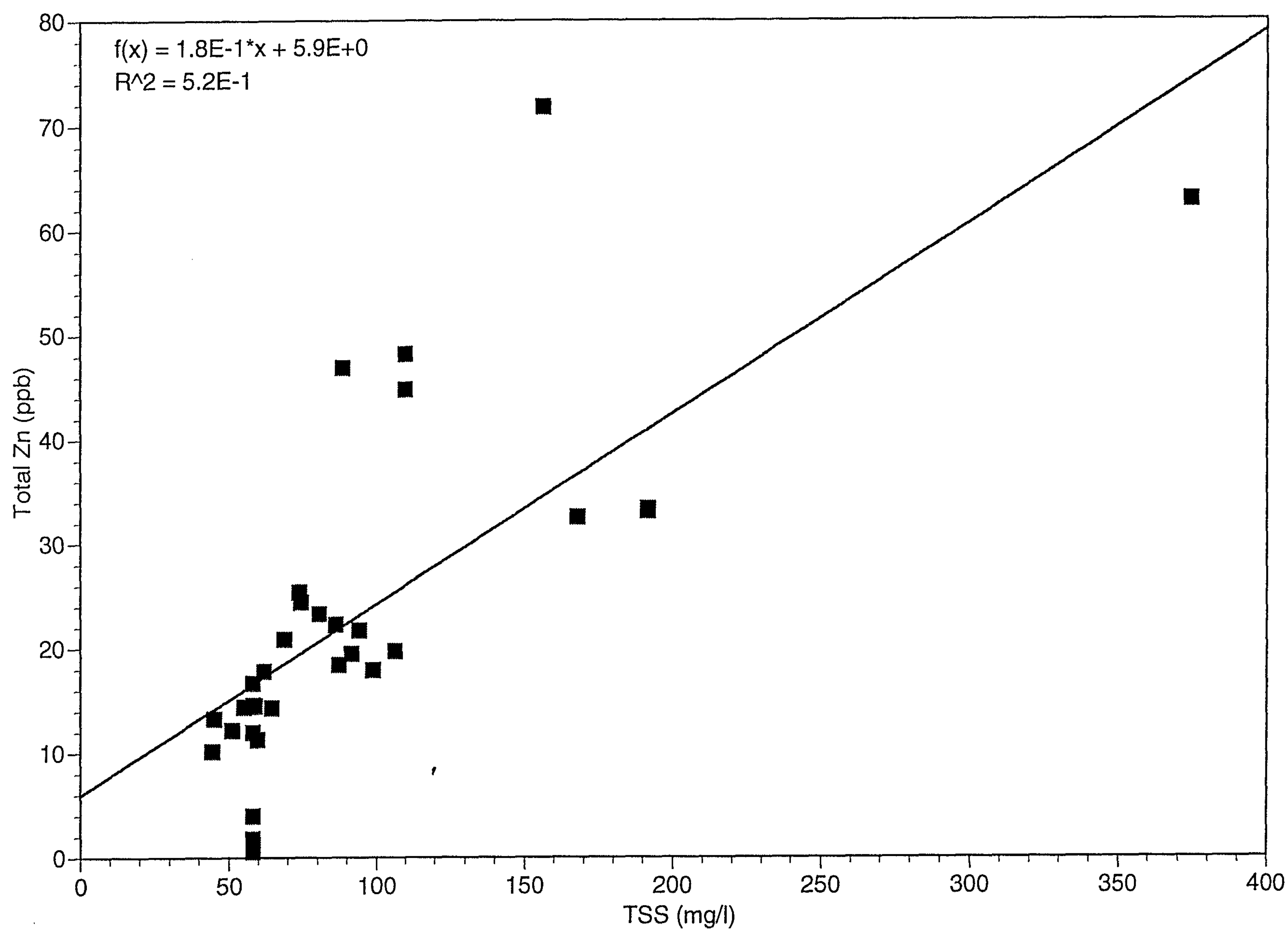


Fig. 37

BPTCP 1994-1995/TSS

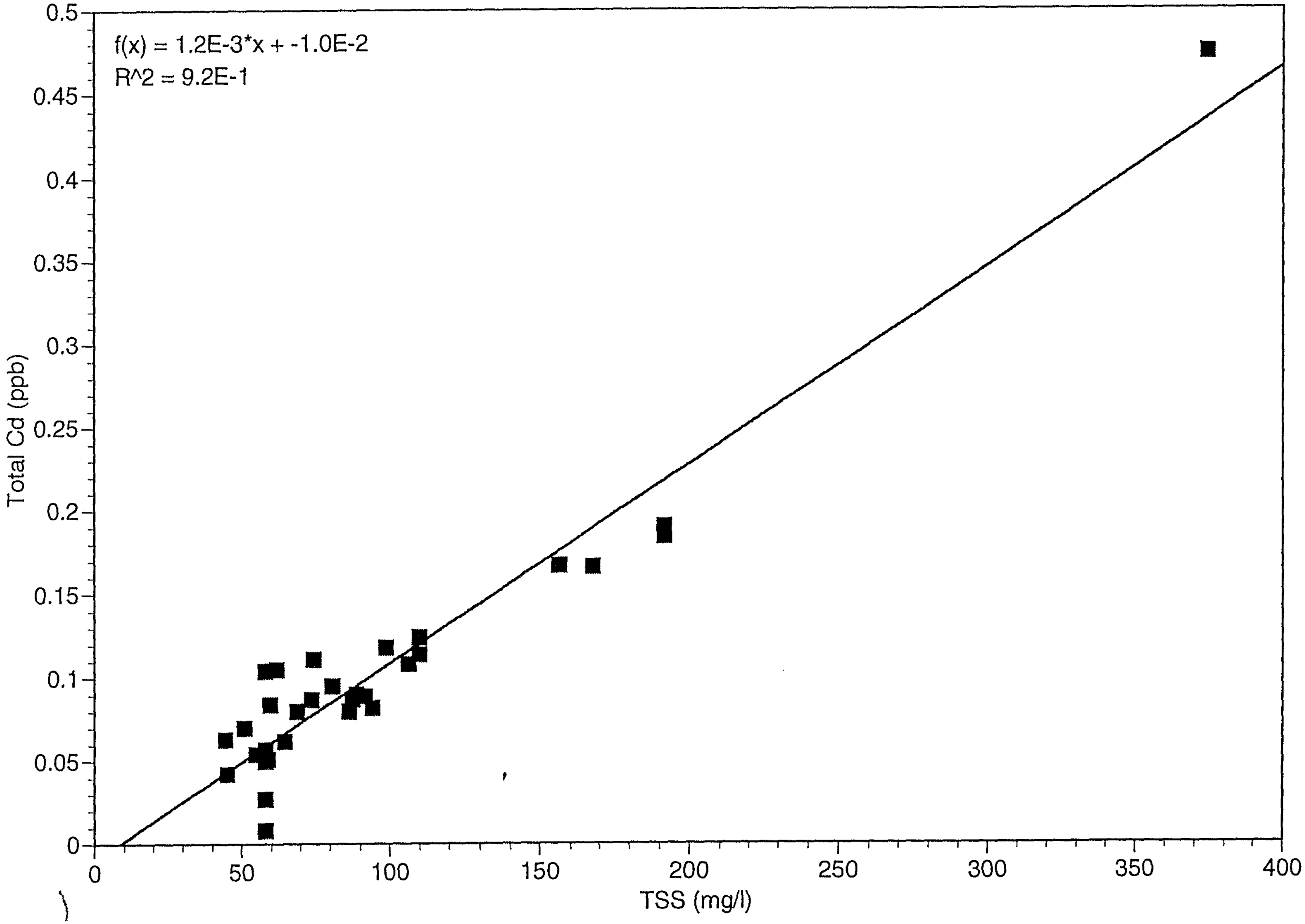
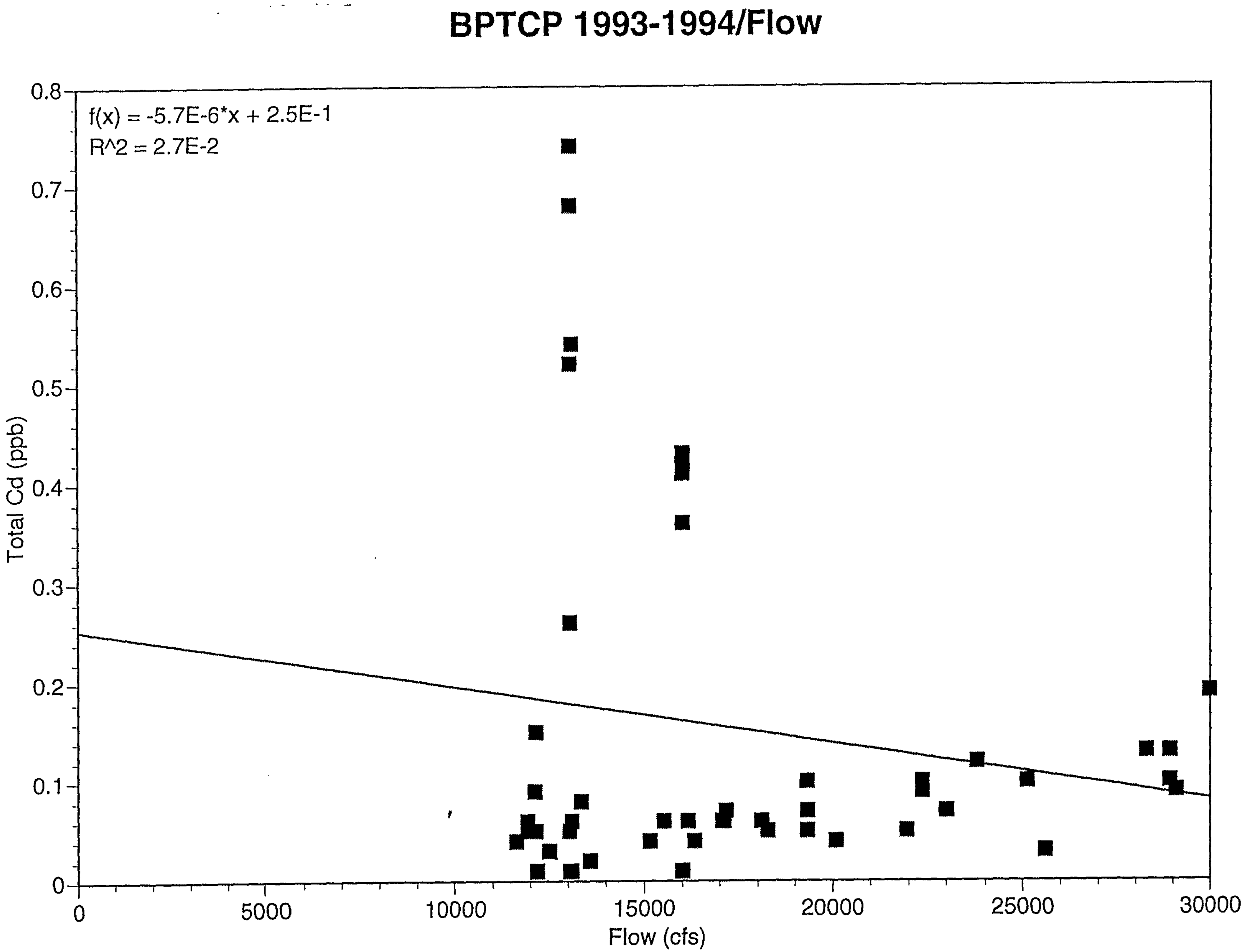


Fig 38

D-042777

D-042777

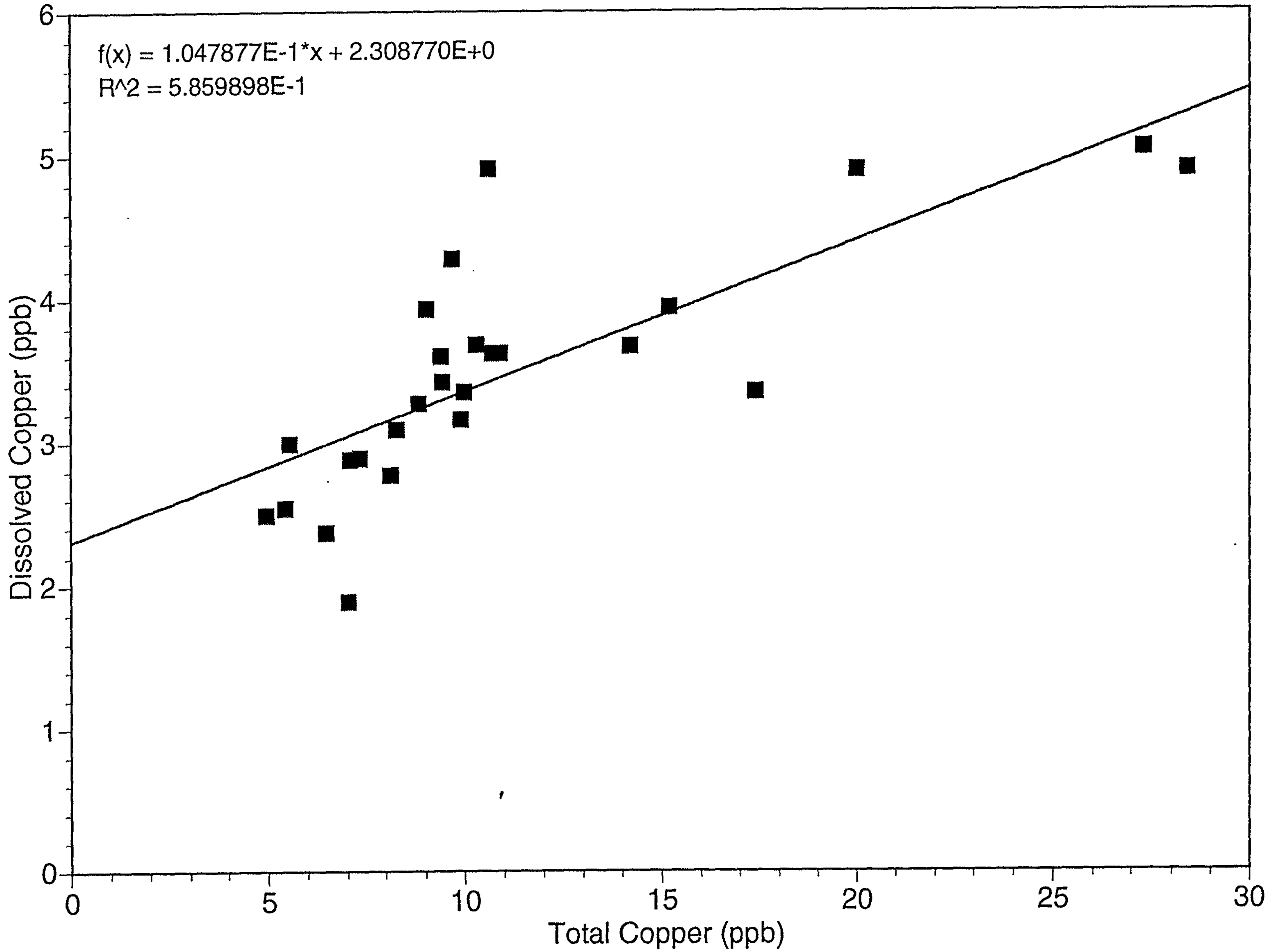


→ Fig 39

D-042778

D—042778

BPTCP 1994-1995/TCu VS DCu



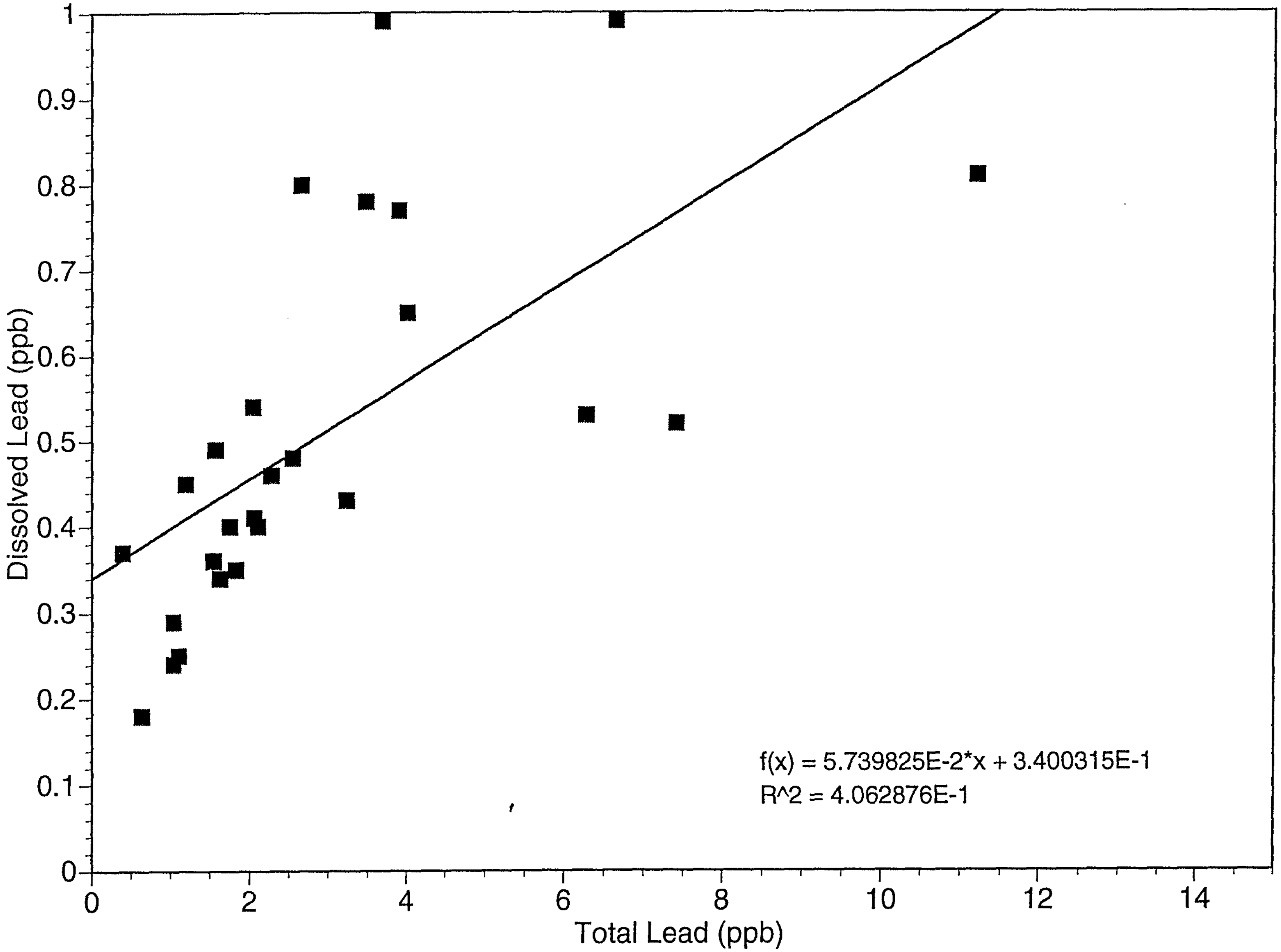
→ Fig 4(b)

D-042779

D—042779

D-042780

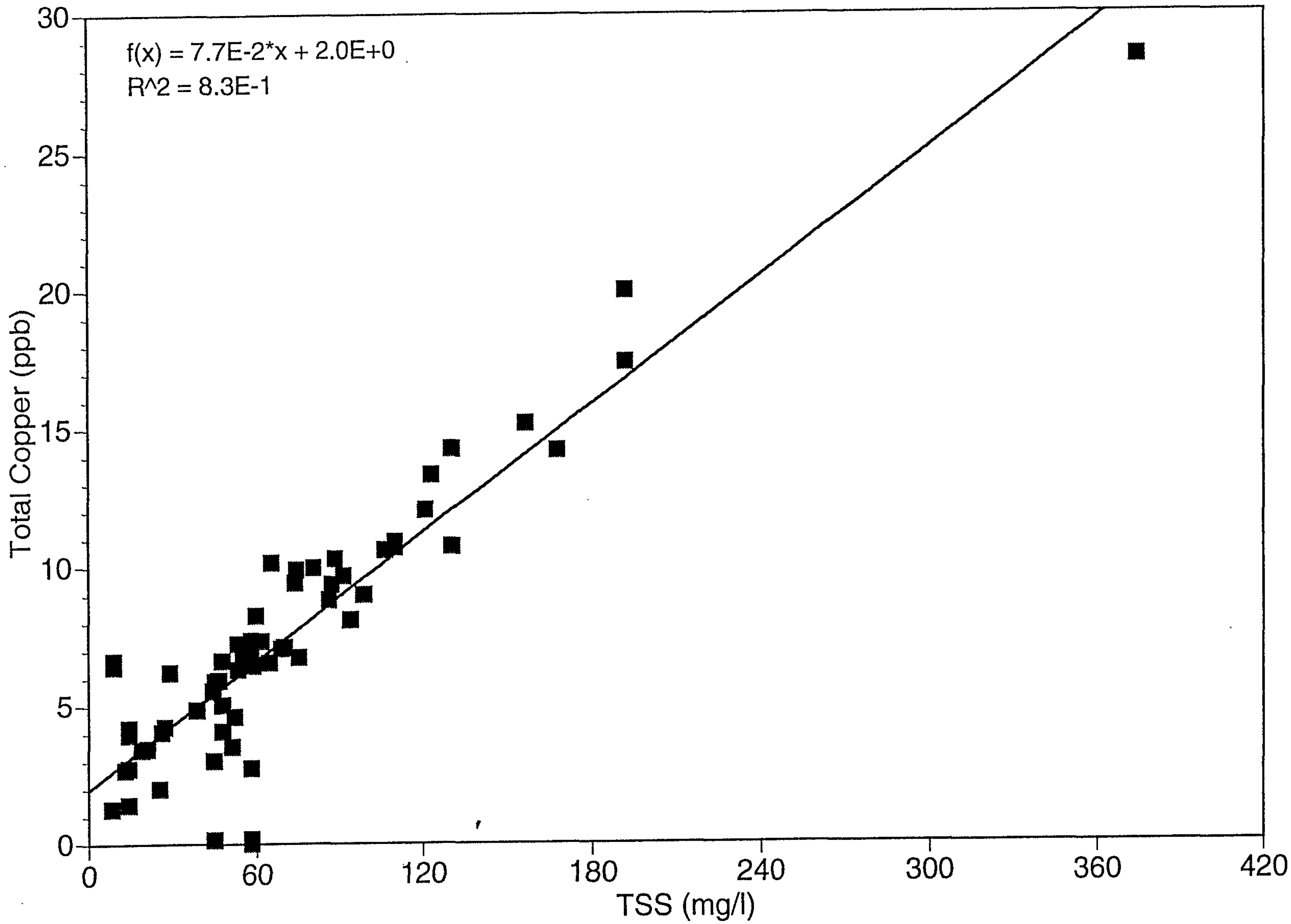
BPTCP 1994-1995/TPb VS DPb



→ Fig 4 !

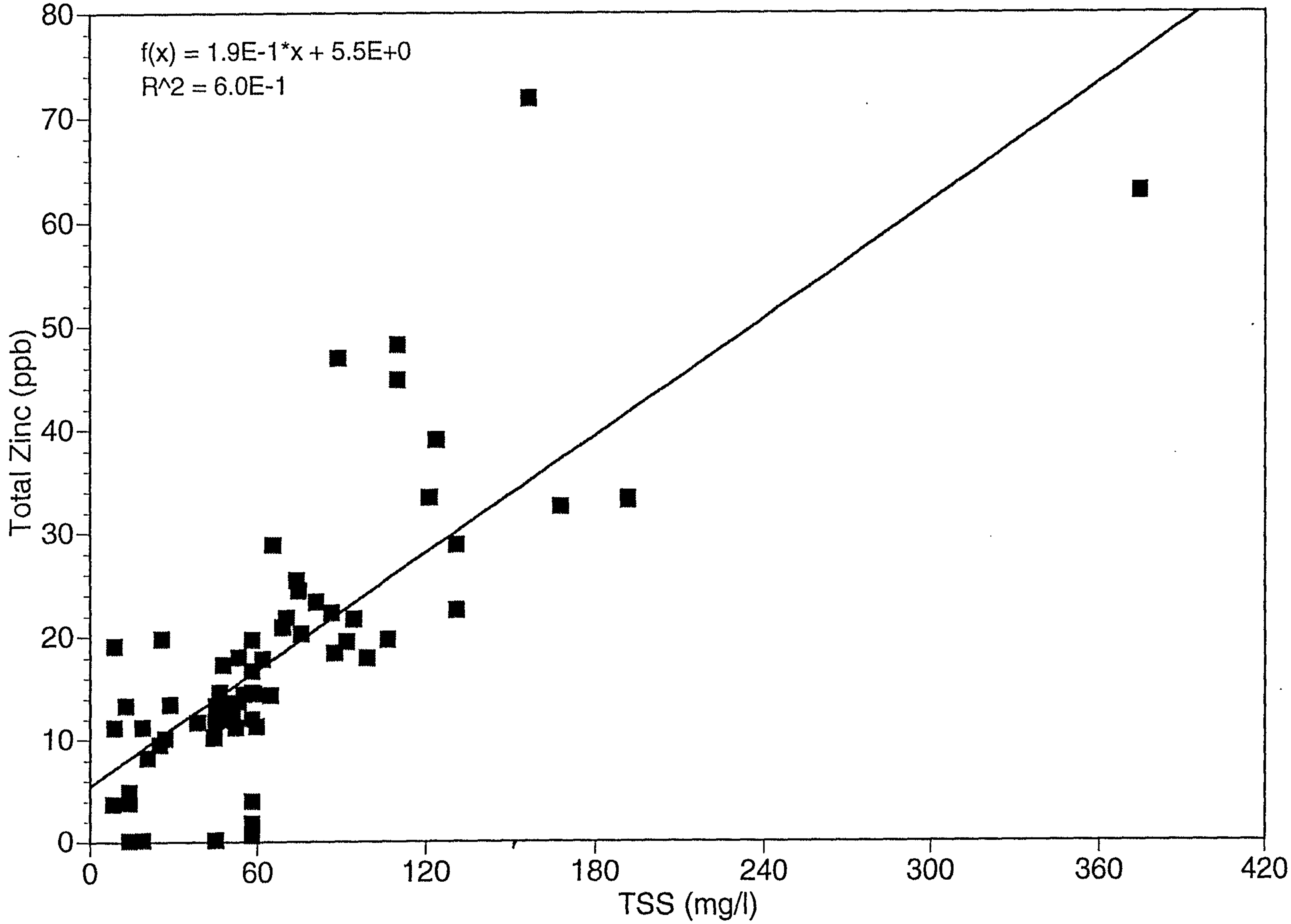
D-042780

BPTCP 1993-1996/TSS



→ Fig 42

BPTCP 1993-1996/TSS



→ Fig 43

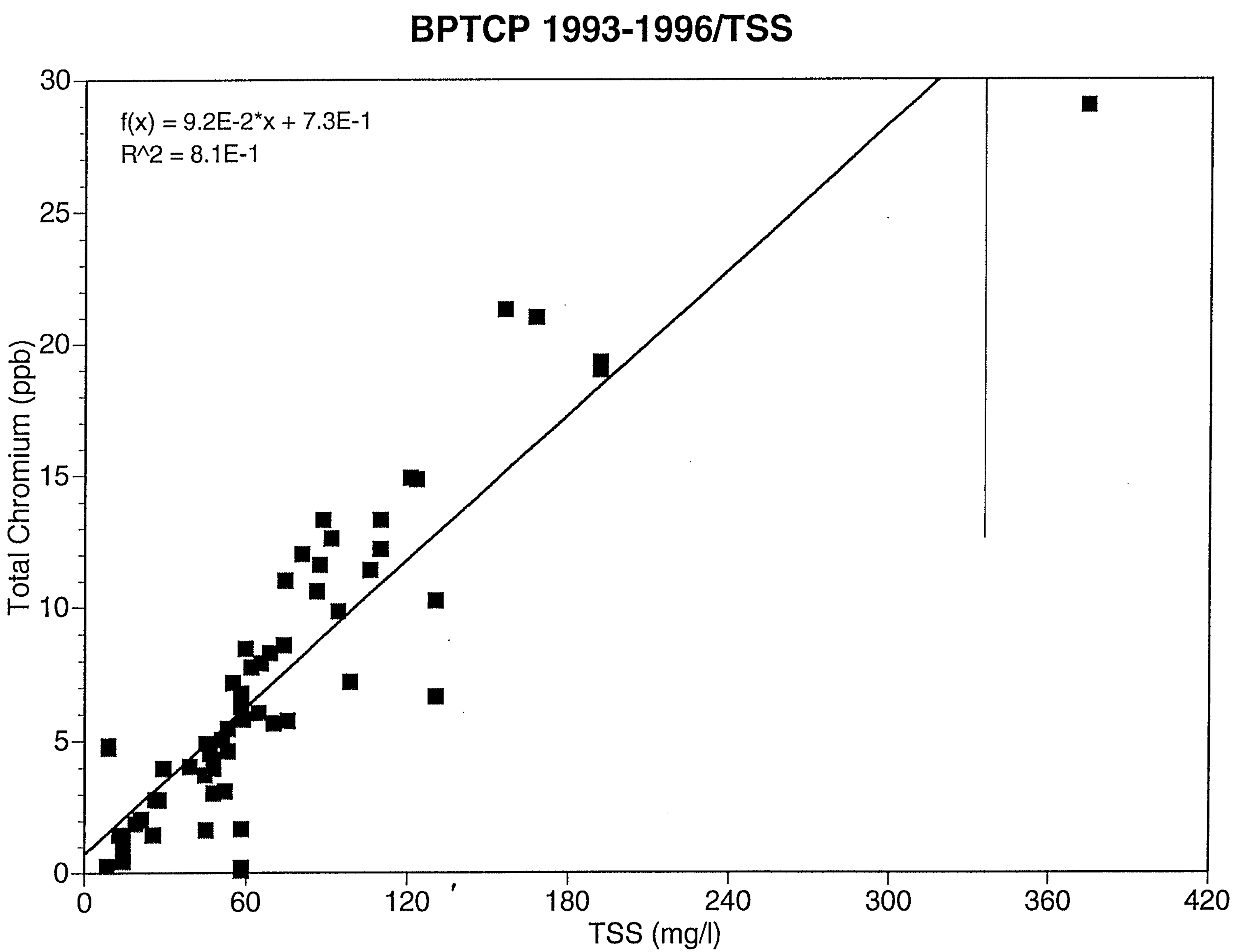


Fig 44

D-042783

D-042783

BPTCP 1993-1996/TSS

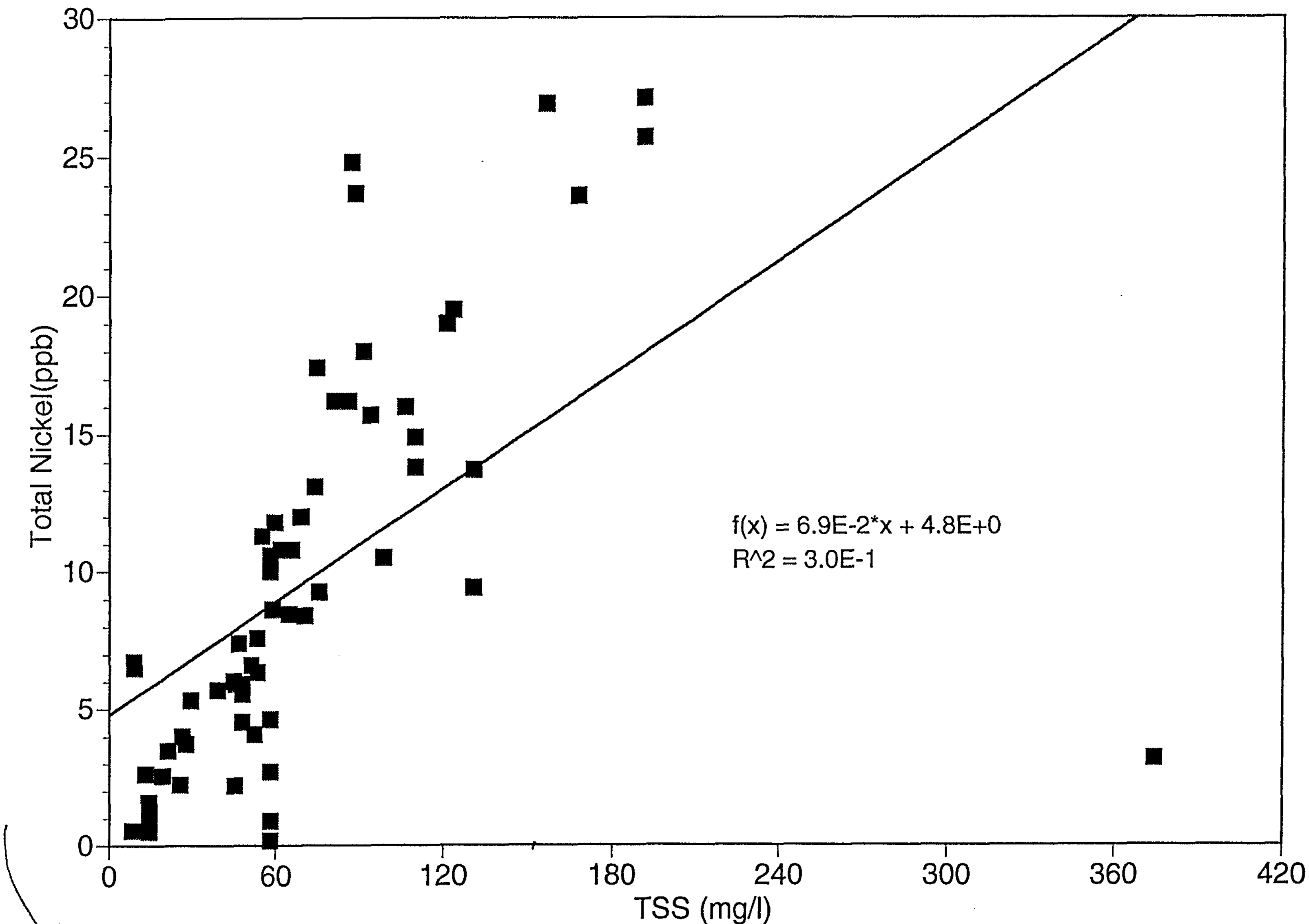
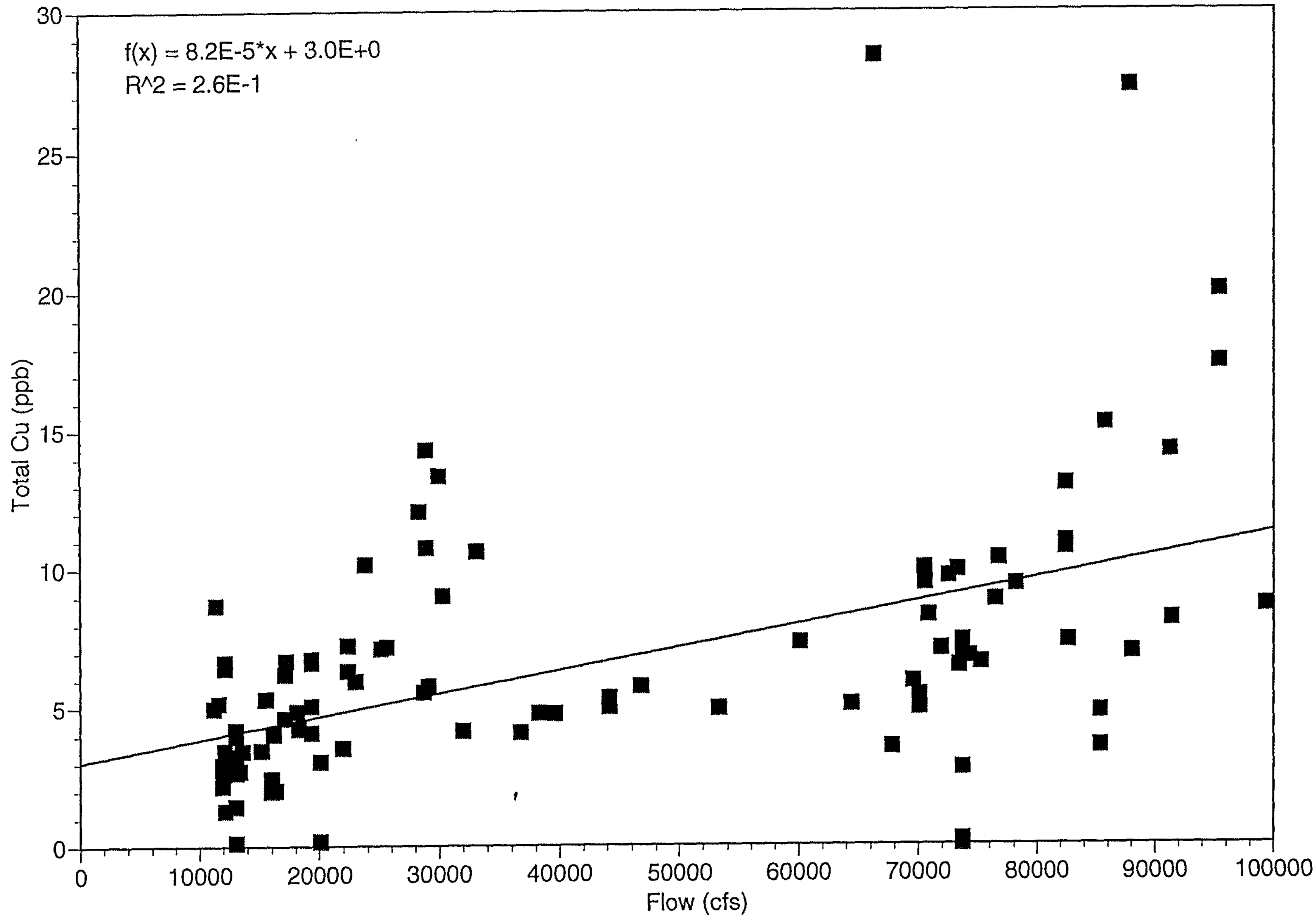


Fig 45

D—042784

BPTCP 1993-1996/Flow



→ Fig 16

D-042785

D-042785

BPTCP 1993-1996/Flow

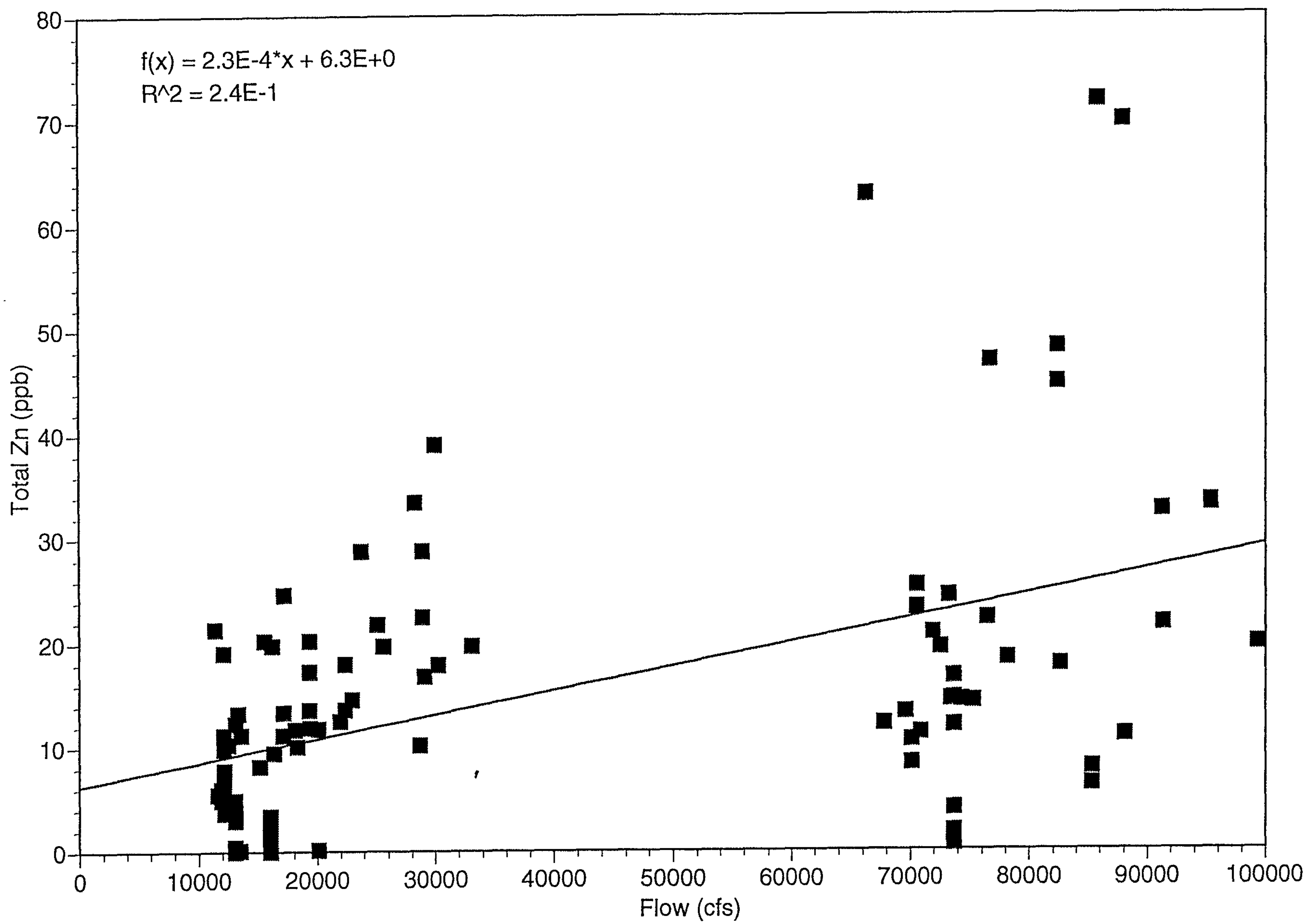


Fig 47

D-042786

D-042786

BPTCP 1993-1996/Flow

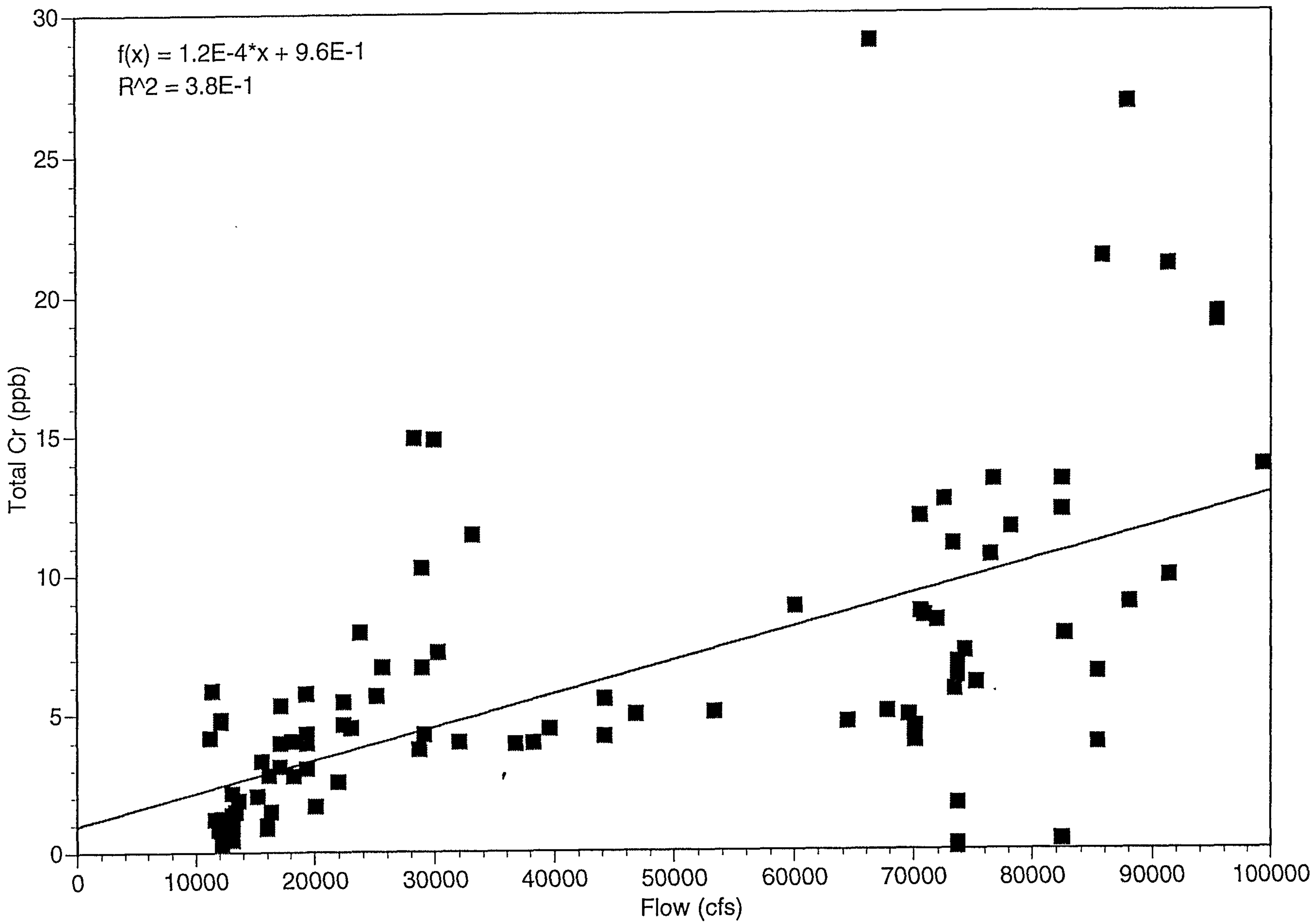


Fig 4/8

D-042787

D-042787

BPTCP 1993-1996/Flow

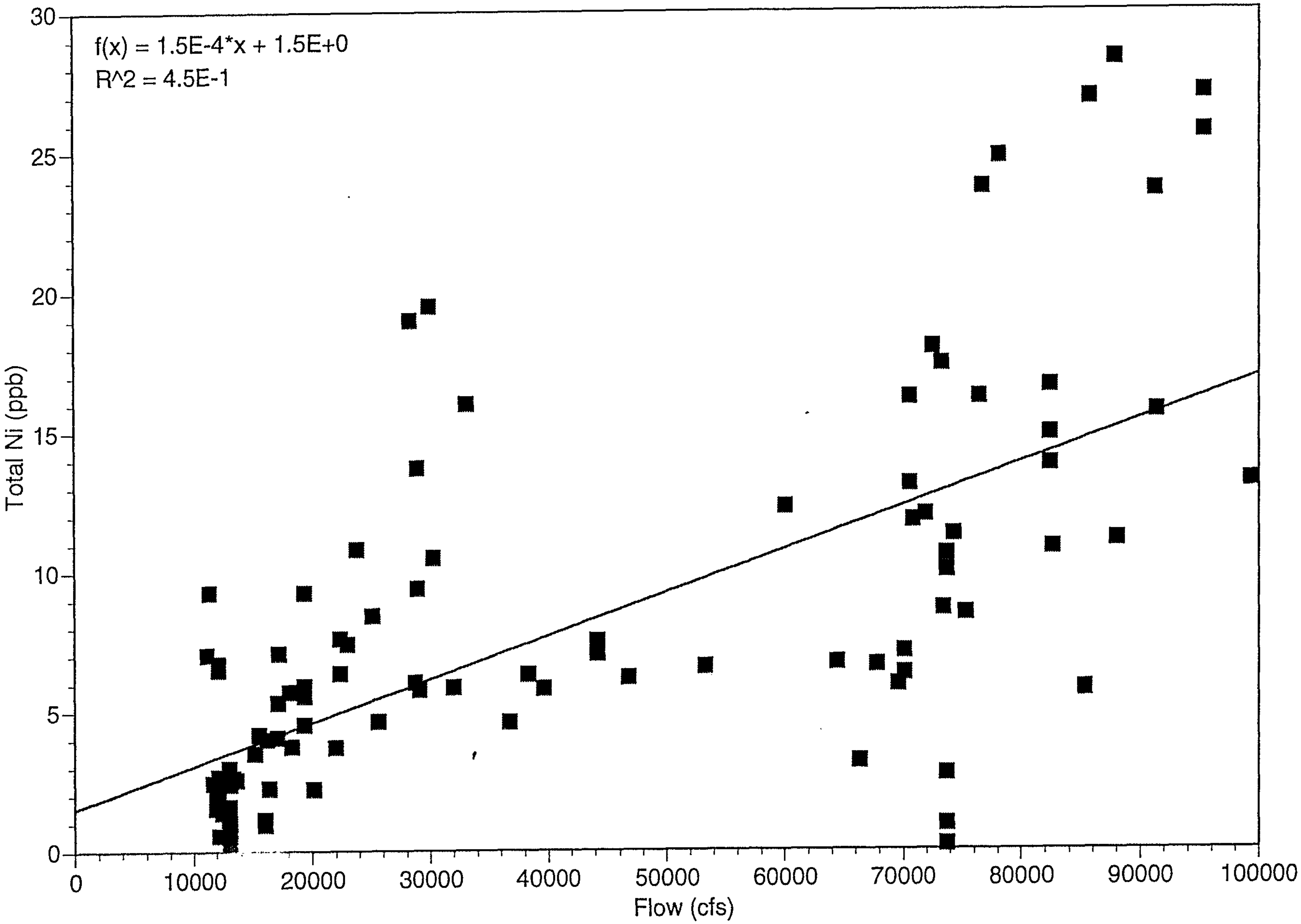
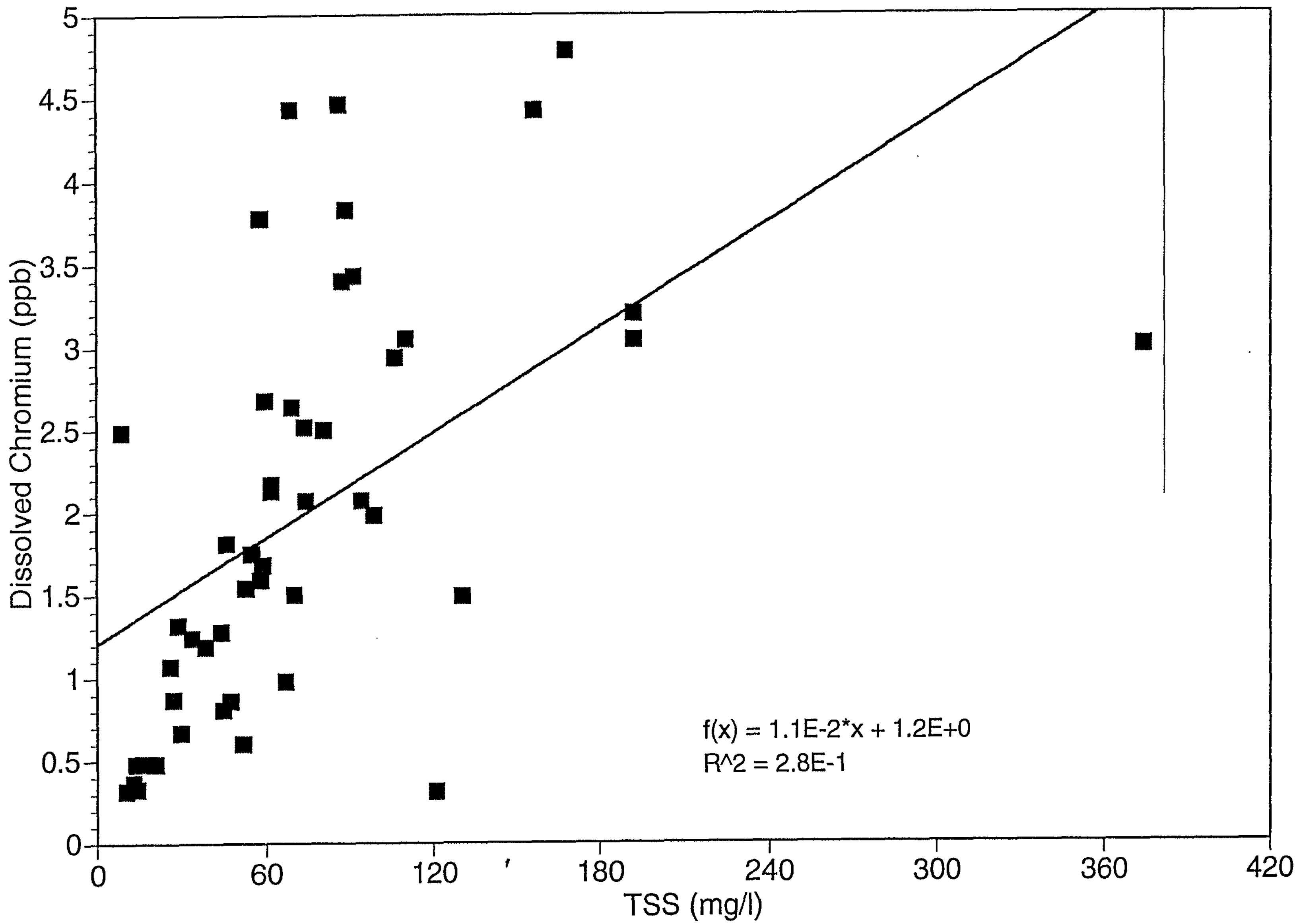
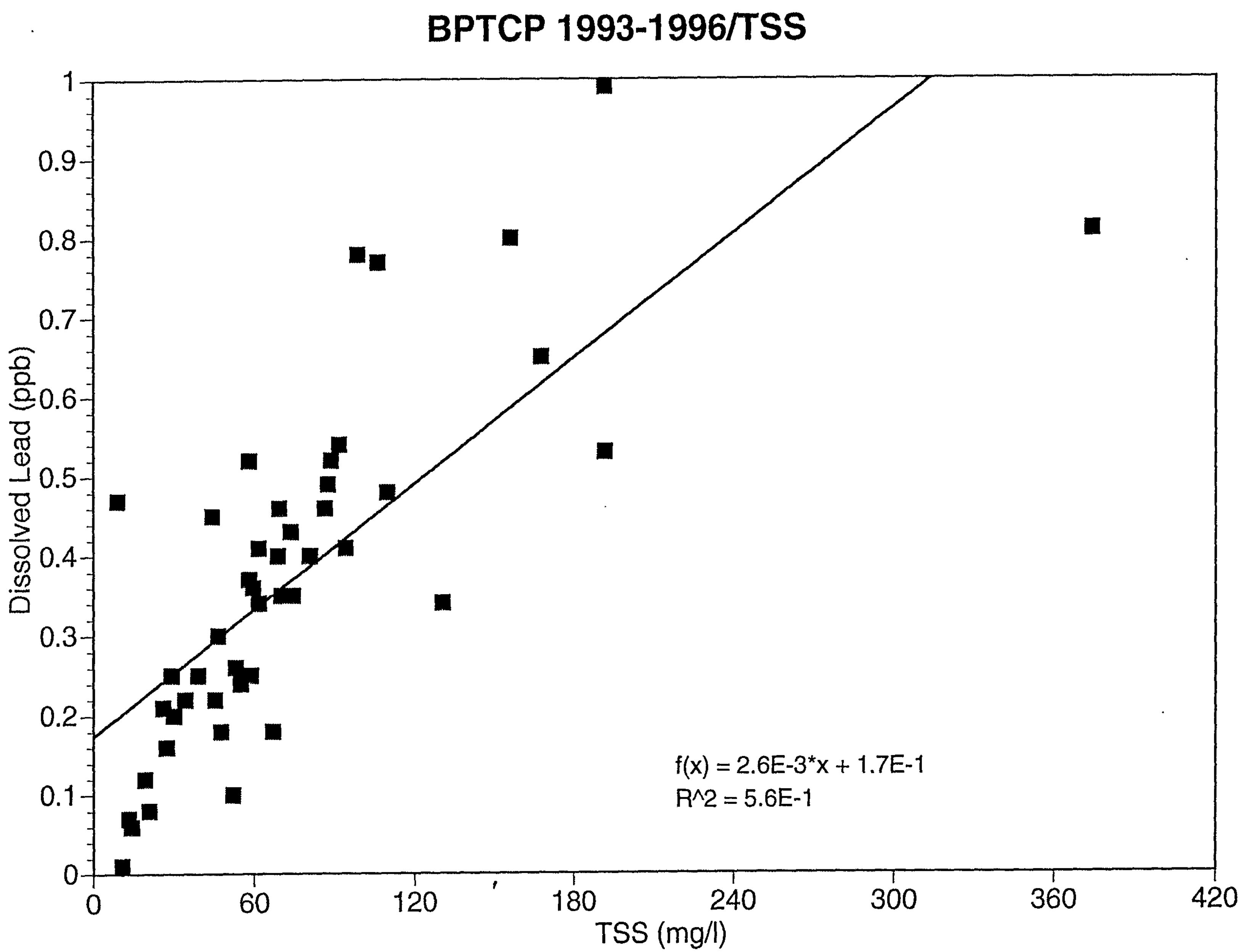


Fig 4(i)

BPTCP 1993-1996/TSS

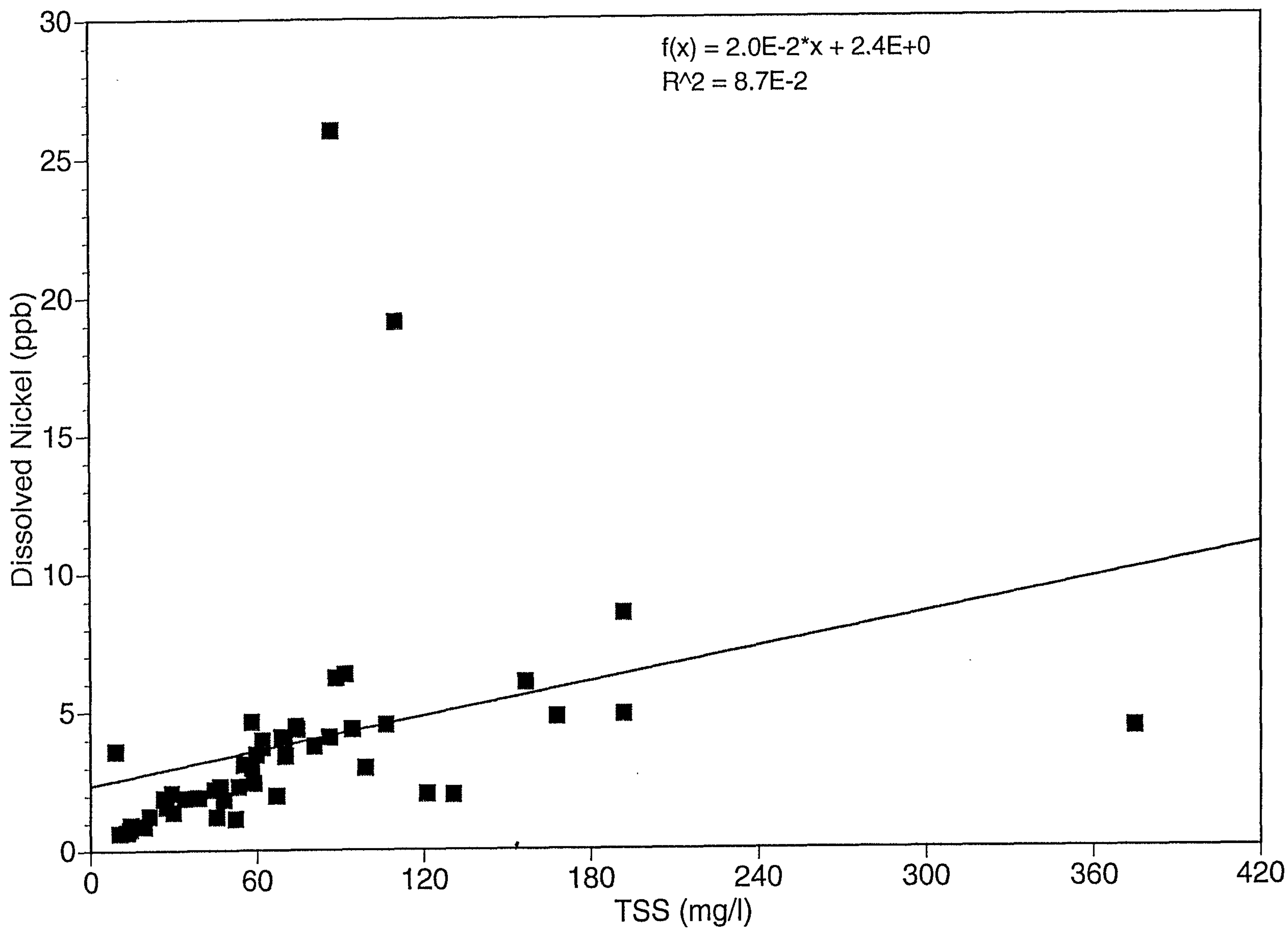


→ Fig 5 D


BPTCP 1993-1996/TSS
Dissolved Lead (ppb)
TSS (mg/l)
f(x) = 2.6E-3*x + 1.7E-1
R^2 = 5.6E-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
60
120
180
240
300
360
420

→ Fig 51

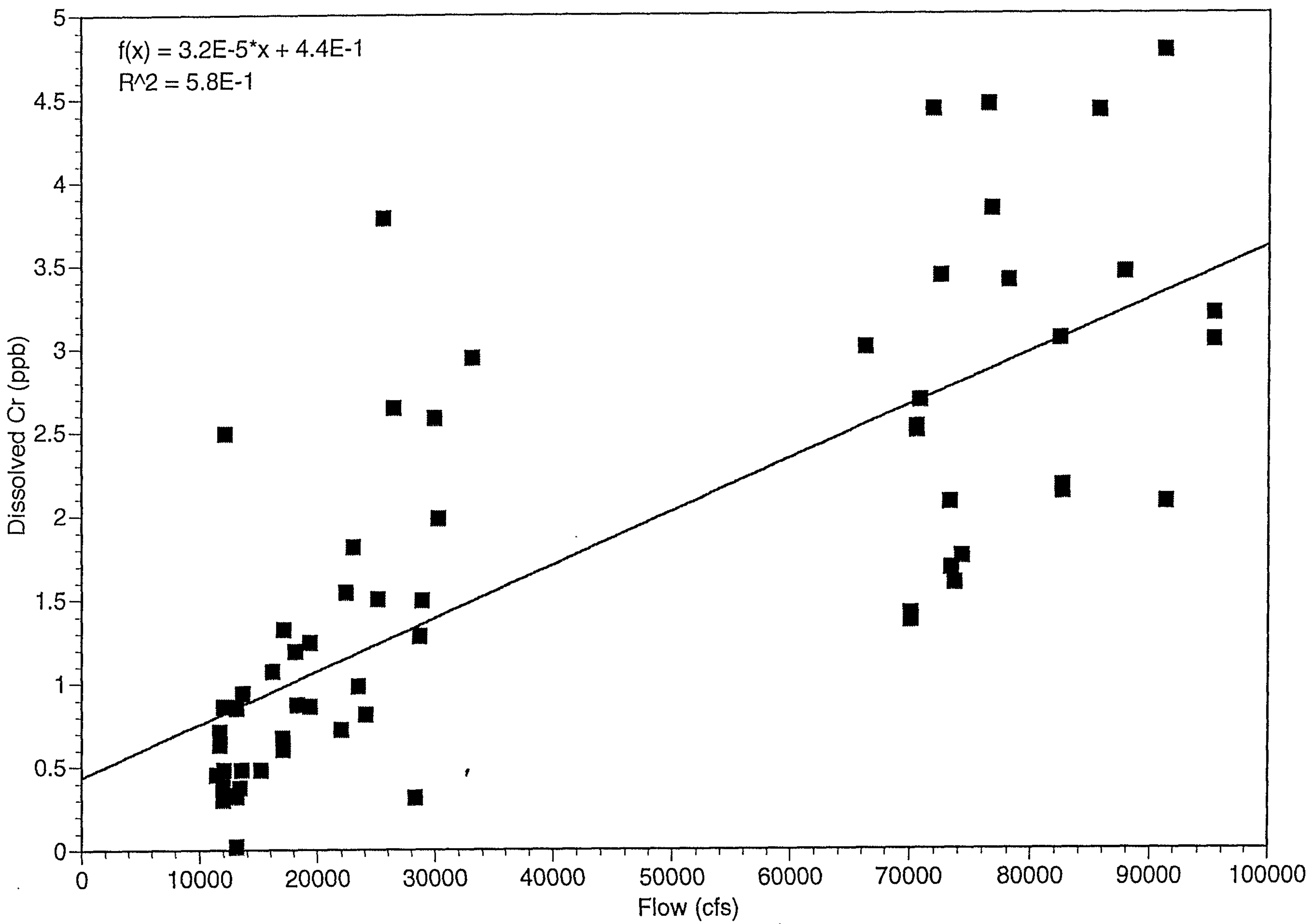
BPTCP 1993-1996/TSS



→ Fig 52

D — 0 4 2 7 9 1

BPTCP 1993-1996/Flow



D-042792

→ Fig 53

BPTCP 1993-1996/Flow

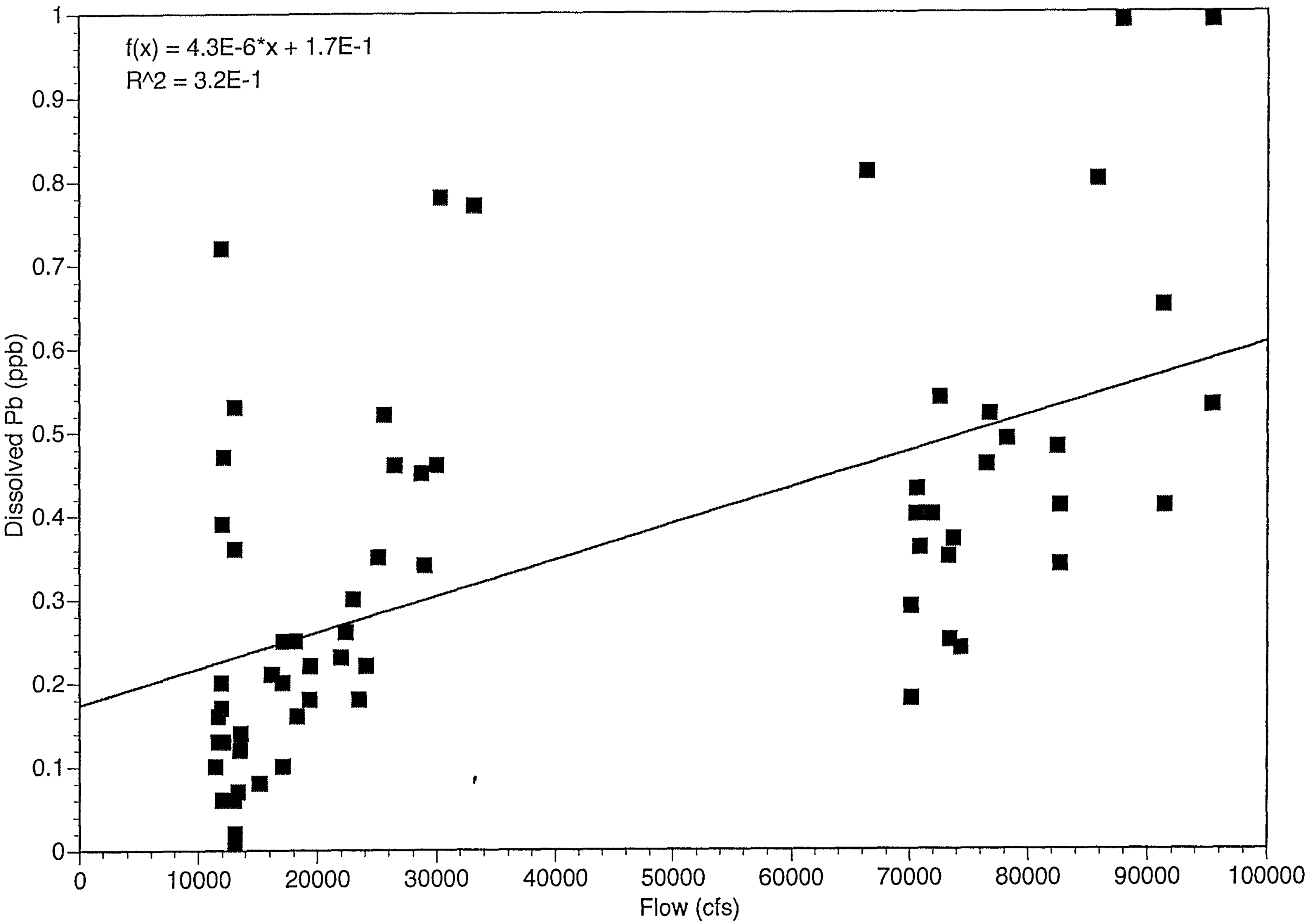


Fig 5(l

D—042793

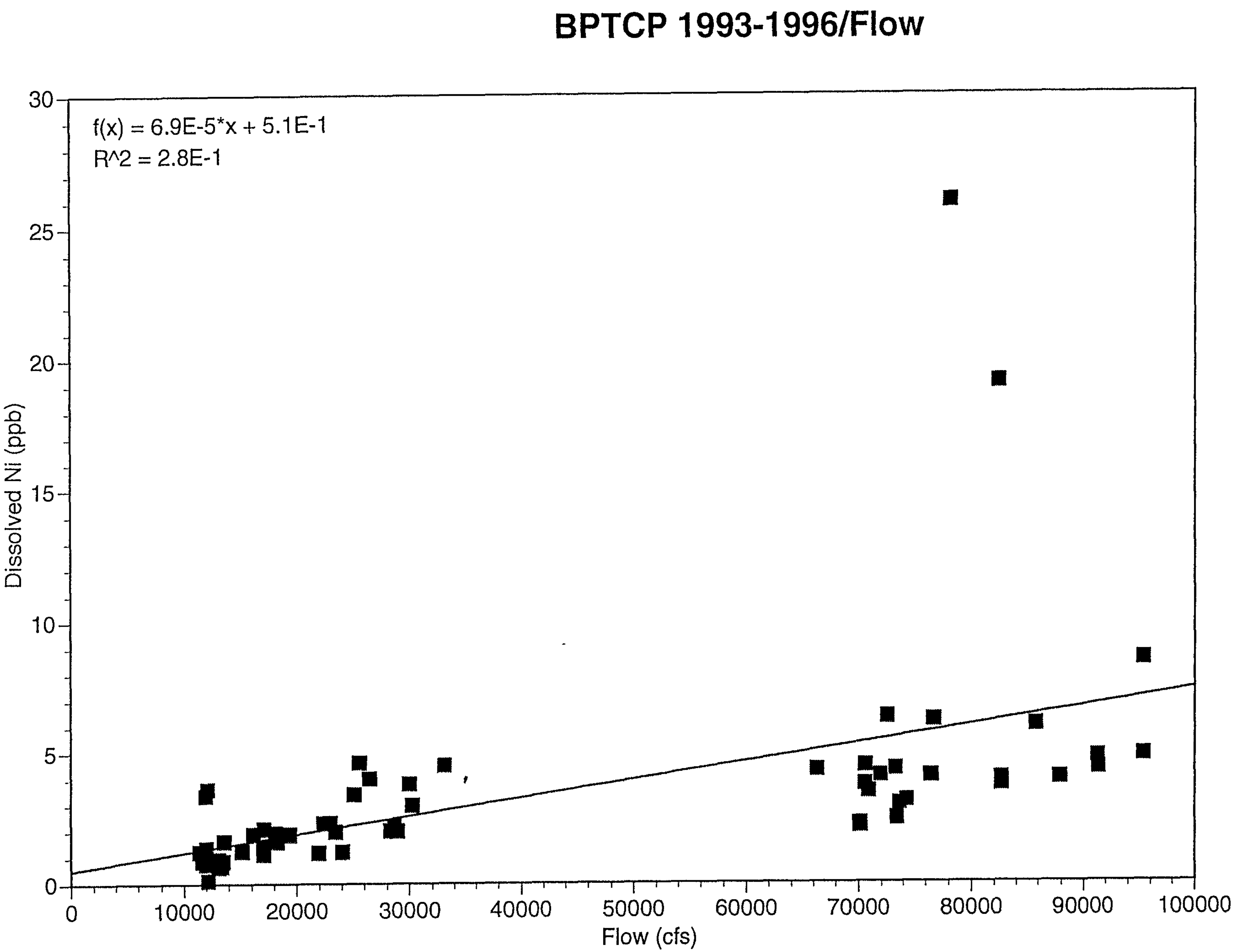


Fig 5 S

D-042794

D-042794

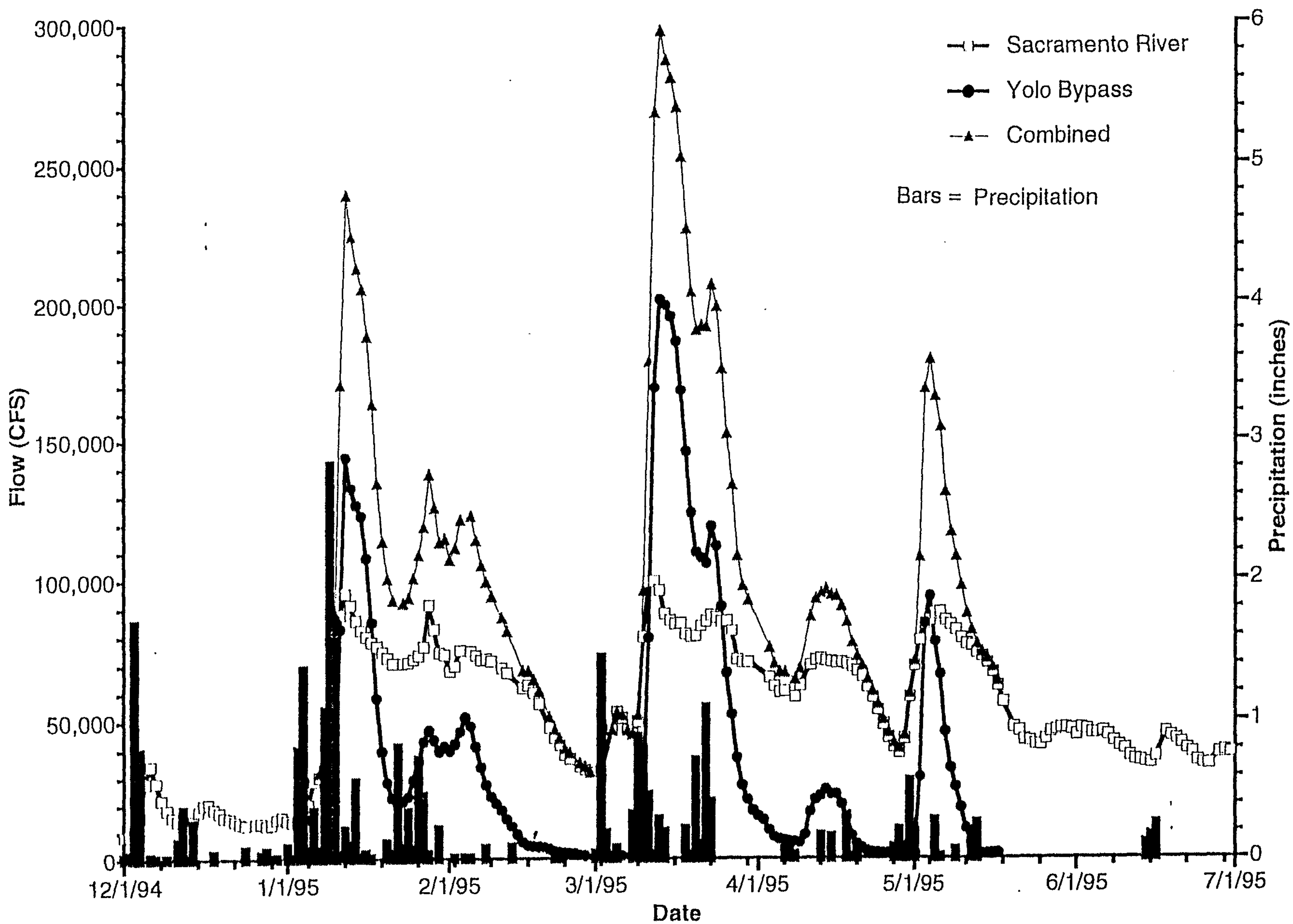


Figure ~~6~~ 56. Precipitation and flow pattern in the Sacramento Basin during the winter and spring of 1995.

APPENDICES

APPENDIX A:

List of Site Locations

The description of monitoring locations are arranged according to the section of the mercury study in which they are discussed. Site numbers refer to Fig. 1 (Delta Study) and Fig. 2 (Metals Source Study).

Sacramento-San Joaquin River Delta Study

Sacramento River @ Greene's Landing (site 1): Sacramento River sampled from end of the U.S. Bureau of Reclamation water quality pier off Randall Island Road. Site is about three miles downstream of Hood. Samples collected at outgoing tide.

Sacramento River @ Hood (site 2): Sacramento River samples collected by boat from mid channel off steps on east bank of River upstream of Hood. Samples collected at outgoing tide.

Mokelumne River (site 3): Samples collected from shore approximately one mile downstream of confluence of Cosumnes River off New Hope Road. Samples collected at outgoing tide.

Ulatis Creek (site 4): Samples collected from mid channel under bridge at Brown Road. Ulatis Creek discharges into Cache Slough.

Skag Slough (site 5): Sampled from middle of Liberty Island Road bridge. Skag Slough is the secondary channel draining the Yolo Bypass. Samples collected at outgoing tide.

Prospect Slough (site 6): Sampled by boat at junction of Prospect Slough and Toe drain. Prospect Slough is the main channel draining the Yolo Bypass. Samples collected at outgoing tide.

Duck Slough (site 7): Samples collected from middle of drain off discharge pump platform. Drain discharges into Miners Slough at Five Points Marina.

Sacramento River @ Rio Vista (site 8): Sacramento River samples collected at low tide in mid channel by boat about one mile downstream of HWY 12 bridge.

San Joaquin River @ Vernalis (site 9): San Joaquin River samples collected off middle of Airport Way Bridge (County Road J3).

Paradise Cut (site 10): Samples collected from middle of south channel off Paradise Road bridge.

Old River at Tracy Blvd (site 11): Samples collected in mid channel off Tracy Blvd. bridge.

French Camp Slough (site 12): Samples collected from mid channel off Manthey Road bridge. Slough is discharged into the San Joaquin River about one mile upstream of Highway 4 Bridge.

San Joaquin River @ City of Stockton (site 13): San Joaquin River samples collected by boat off entrance to McLeod Lake.

Middle River @ Bullfrog (site 14): Middle River samples collected on an incoming tide at mid channel off Bacon Island Road Bridge.

San Joaquin River @ Point Antioch (site 15): San Joaquin River samples collected from boat in mid channel at low tide off Point Beenar. Site is about five miles upstream of confluence of Sacramento River.

Chipps Island: Sacramento River samples collected from boat in mid channel off Chipps Island at lower low tide.

Grizzly Bay: Sample collected by boat at lower low tide in mid Bay off pilings.

Martinez: Samples collected by boat at lower low tide in mid channel about two miles downstream of HWY 680 bridge.

Metals Source Study

Shasta Dam (site 1): Sacramento River sample collected from east bank below Shasta Dam at Powerhouse.

Cypress Bridge (site 2): Sacramento River sample collected in mid channel from Cypress Avenue bridge.

Little Cow Creek (site 3): Sample collected from mid channel off the Dersch Road Bridge outside of Anderson.

Balls Ferry (site 4): Sacramento River sample collected in mid channel from Balls Ferry Road bridge.

Cottonwood Creek (site 5): Sample collected in mid channel off HWY 5 frontage road bridge about one mile south of the town of Cottonwood.

Bend (site 6): Sacramento River sample collected in mid channel from Bend bridge Park.

Road a-8 (site 7): Sacramento River sample collected in mid channel off County Road A8 bridge near Tehema and the Mills Creek Recreation Area.

Road a-9 (site 8): Sacramento River sample collected in mid channel from South Avenue bridge at Woodsen State Recreation Area.

Ord Ferry (site 9): Sacramento River sample collected in mid channel from Ord Ferry Road bridge.

Colusa (site 10): Sacramento River sample collected on west side of channel off River Road bridge.

Sutter Bypass (site 11): Sample collected about one third of way across Bypass on north side of channel off HWY 113 bridge.

Sacramento Slough (site 12): Sampled from the Reclamation District pumphouse at Karnack.

Feather River (site 13): Sample collected by wading off intersection of Garden Highway and Lee Road.

American River (site 14): American River sample collected in mid channel off bridge at Sacramento State University in the City of Sacramento.

Greene's Landing (site 15): Sacramento River sampled from end of the U.S. Bureau of Reclamation water quality pier off Randall Island Road. Site is about three miles downstream of Hood. Samples collected at outgoing tide.

Cache 102 (site 16): Bank sample collected immediately downstream on west side of Creek adjacent to the Road 102 bridge.

Putah Creek (site 17): Sample collected in mid channel off Mace Blvd. bridge near Davis.

West Yolo Bypass (site 18): Sample collected from the western levee of the Yolo Bypass about a half mile north east of the Interstate 80 bridge.

East Yolo Bypass (site 19): Sample collected from the eastern levee of the Yolo Bypass near the Interstate 80 bridge.

Skag Slough (site 20): Sampled from middle of Liberty Island Road bridge. Skag Slough is the secondary channel draining the Yolo Bypass. Samples collected at outgoing tide.

Mokelumne River (site 21): Samples collected from shore approximately one mile downstream of confluence of Cosumnes River off New Hope Road. Samples collected at outgoing tide.

Vernalis (site 22): San Joaquin River samples collected off middle of Airport Way Bridge (County Road J3).

APPENDIX B:

Raw Metal Analysis Data